SPATIAL AND TEMPORAL GEOMORPHIC VARIABILITY AND COASTAL LAND USE PLANNING, NORTHEAST FLORIDA

By

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To Evelyn and Margaret, for adventure and intellect; and to Kurt, Jeremy, and Emma, for their patience and understanding

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Abstract of Dissertation Presented to the Graduate School
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The research quantified the influence of local geomorphology of coastal areas on the suitability of existing development patterns and future land use plans. Brevard and St. Johns County (located on the east coast of Florida) were studied from 1972 to 1999. The State of Florida requirement for comprehensive plans containing future land use designations provided base data for development of a policy-evaluation model.

Impacts of the physical characteristics of the coastline on the number and density of dwelling units, impervious area, and development potential were evaluated at 1 km intervals. Geomorphic variables (beach width, maximum dune height, crest position, and shoreline change) interact with development patterns and future land use designations, and are determined by location. The net and total change are measures of the dynamic characteristics used to evaluate temporal variations.

Results supported the anticipated relationships among wider beach width, higher levels of impervious area, density, commercial hectares, and future land use. However, development levels are more intense in areas with lower maximum dune heights, suggesting that low dunes are a preferential condition for development. The position of

the dune crest height was used as a proxy for the condition of the dune field. A low distance from the crest to a fixed point on the profile represents a stable local environment. The research showed this to be inconsistent with the data, and concludes that movement of the crest position seaward represents dune field progradation.

Analyses at the county level showed contrasting approaches to future land use designations and coastal development. Beach width was a determining variable in St. Johns County, whereas dune height was more important in Brevard County. The intensity of development is consistent with the long-term change in both jurisdictions. This work broadens understanding of the interaction of the physical environment and human occupation in the coastal zone. Determining relationships between the physical parameters and types of development provides tools to help coastal managers, geomorphologists, land use planners, and public officials to maximize access, while minimizing unintended impacts in coastal areas.

CHAPTER 1
INTRODUCTION

> the historical dimension of geomorphology prevents it from being 'reduced to physics', and secondly, the key role that human activities (which defy all rationality) play in modifying the Earth's surface ensures a unique place among the sciences.
> John D. Jansen, Gemorphlist, May 2002

Historically, the natural and physical features of the locale have influenced settlements. Ancient cities were sited at river confluences, in flat areas of mountainous terrain and at strategic defensive locations. Early coastal development began inland of passes giving settlers access to the ocean. Although barrier islands were not the areas of choice for settlement because of their isolation and lack of access, bridge construction allowed development of barrier islands. The coastal zone is recognized as a dynamic environment, and extensive fluctuation of this environment may make it inappropriate for intense development.

Development along the coastal barriers has been driven by a variety of issues. This research investigates the level to which development is permitted and occurs in preferentially safer, or more stable areas (with higher dunes or wider beaches). The work retrospectively examined the interaction between natural and physical features (specifically the geomorphology) and land use changes. The research evaluated the extent to which characteristics of the immediate area (dune height, and beach width) influenced patterns of development. Aerial photography and Geographic Information Systems are used in the evaluation of the dynamics of the local environment and the impact on past, current, and future land use patterns in two counties in coastal Florida.

The main goal was to determine the extent to which the local geomorphology of the coastal environment shapes existing and future patterns of development. Dolan (1976, pp. 76) said that "planners and decision-makers responsible for the management of the shoreline resources must

have a basic understanding of the nature of the inshore zone." This work explores the extent to which the understanding of the local geomorphology has policy direction and resulting infrastructure and development. The existing concentrations and projected influx of coastal residents make these patterns of development an important focus for geomorphologists, land planners and coastal managers.

Florida has the longest shoreline in the coterminous United States, and it is fringed by barrier islands. Florida has 1,176 km of coastal barriers (U. S. Department of Interior, 1983); 741 km (63 %) was developed in 1983. The coast of the United States has 295 barriers (Reesman, 1994) and Florida has 80 barrier islands containing 189,000 hectares of land (Leatherman, 1982).

Coastal development in Florida varies from the high-rise condominium canyons of southeast Florida, to the 1950s beach shacks of the panhandle. Traditionally coastal development began inland of passes giving settlers access to the ocean. Barrier islands were not the areas of choice for settlement because they were isolated and lacked access. Once bridges were built development progressed onto and along the barrier islands. The influence of the geomorphology of the locale is important for coastlines containing a mix of single-family homes, multi-family condominium and small commercial areas. The coastal geomorphology and development patterns of two coastal areas (Brevard county in central Florida and St. Johns County in northeast Florida) are investigated during three time periods. The two coastal areas investigated are long inhabited and historically significant.

Use of the coast has evolved over time. This brief review of ancient development and coastal habitation provides historical background for the 27-year study period (1972 to 1999). Lencek and Bosker (1998) chronicled the evolution of coastal use, characterizing it as the

> transformation of the beach from an alien inaccessible, and hostile wilderness devoted to conquest, commerce and exploration, and the primal customs of tribal cultures, into a thriving, civilized, pleasure- and recreation-oriented outpost of Western life. Lencek and Bosker, 1998, pp. xx.

Anthropologists have investigated prehistoric barrier island settlement in Georgia, South Carolina and Florida (McMichael, 1977; Miller, 1980). Settlement patterns show a preference for elevated sites on the relict Pleistocene sand ridges, particularly in areas where intertidal creeks provided access to the back barrier lagoons and marshes in the interior (McMichael, 1977). In St. Johns county occupation of coastal areas may have been seasonal and short-term (Miller, 1980), and determined by the productivity of the lagoon and adjacent environments. There is no evidence of ancient settlement, on the seaward side of barrier islands (Miller, 1980).

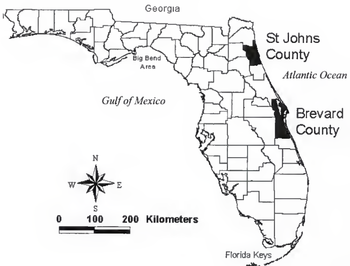

Figure 2-1. Study areas: Brevard and St. Johns counties, Florida

After World War II, the automobile made the shoreline increasingly accessible. Until 1950, coastal development had existed in the form of exclusive resorts and coastal areas adjacent to large metropolitan areas that were accessible by locomotive. Traveling to the coast by camper

afforded convenience and economy, and became so popular that trailer parks along the shore proliferated. In 1940, there were 3,500 trailer camps in the US (Lencek and Bosker, 1998). In 1972, both Brevard and St. Johns counties had mobile home and recreational-vehicle parks; evidence that the coast was once considered a temporary venue. Ultimately it was not the locomotive, automobile or affluence that opened the Florida coast to year-round vacationing and permanent dwelling; it was the advent of air conditioning use. Air conditioning was available in the 1930s, but was not in widespread use until the mid 1950s.

Research Purpose

Pressure is increasing between those who want to live on the coast and those who think it should be preserved in its natural state (Ullmann et al, 2000). Most studies on human and coastal interaction focus on human influence on natural systems rather than on the geomorphology's influence in humans. This work considers the possibility that local land use policy and human development variables are influenced by the coastal environment, or geomorphology. This research quantifies the way in which coastal development has been influenced by the geomorphology along the barrier shorelines of St. Johns County in northeast Florida and Brevard County in east central Florida, over 27 years. Four hypotheses are considered.

1. Local geomorphology at each time interval impacts human variables at the same interval
2. The dynamic geomorphology impacts human variables
3. There are temporally lagged relationships between the actual and dynamic geomorphology variables and the human variables.
4. The dependent variables will have different relationships with the independent variables in the two separate study areas.

CHAPTER 2
LITERATURE REVIEW

The influences of anthropogenic activities are integral to coastal geomorphology (Malone, 2003, Sherman and Bauer, 1993). However, coastal research has predominately focused on human impacts on the coastal zone, rather than the influence of the physical environment. Human impact has been reviewed at the macro scale (Brown and McLachlan, 2002; Clark, 1976; Clark, 1997; Phillips, 1988; Phillips, 1997; Viles and Goudie, 2003; Viles and Spencer, 1995) and micro levels (Conway and Nordstrom, 2003; Gares, 1987; Nordstrom, 1994; Nordstrom et al., 2002; Sherman and Bauer, 1993). Nordstrom (1994) recognizes human activity as an integral part of the coastal system. He discusses the lack of literature specific to human altered coasts. "Natural landscapes are a myth, that human agency is not an intrusion in the coastal environment so much as it is now part of the coastal environment." (Nordstrom, 1994, pp. 508) Others contend that the natural system must be understood before human influences can be evaluated (Sherman and Bauer, 1993). The interaction between physical and human geography has been also been described as a form of landscape geography, bridging the systematic and regional geography approaches (Lundberg and Handegard, 1996).

The natural or physical environment is influenced by, and also influences human factors. This research evaluated the weight of the physical environment as a factor affecting human variables. Lundberg and Handegard (1996) investigated coastal agricultural uses to evaluate how humans have adapted to the use of the environment over time. Adjacent agricultural practices may be dissimilar in identical environmental conditions, suggesting that a variety of feedback loops influence the spatial patterns. Lundberg and Handegard (1996) state that the "landscape is a reflection of environmental, and social conditions and processes in society" (pp. 168). In New Zealand, geomorphology has been used to determine the potential uses of areas (Hails, 1977).

Areas were divided into those suitable for high-intensity activity and areas that should be maintained in a natural state. Similarly, North Carolina has used zoning restrictions for hazard-mitigation purposes (Bush et al., 1999). The geomorphology provided the basis of land use restrictions that were enforced through zoning controls.

Use of Spatial and Temporal Data in Geomorphology

The field of geomorphology was originally characterized by landscape evaluation using fieldwork. Later, modeling processes and laboratory simulations became important (Hooke, 1999). For each stage of geomorphological research the importance of the data has been paramount. Perfect data would be spatially and temporally precise, accurate, readily available, and calibrated. The shortfalls of data must be acknowledged and accommodated in successful research. There are four categories of data; in-situ, remotely sensed, secondary data, and simulated data (Lucas, 1996). This research used predominately secondary data collected by the State of Florida, remote data (aerial photography) and simulated data collected from county comprehensive plans. Field research or in-situ investigations augment the data. These data are combined and analyzed using Geographic Information Systems (GIS). Geomorphological research has progressed from simple one-dimensional analyses to the complex spatial capabilities afforded by digital media (Vitek at al., 1996). The research considered spatial detail alongshore and temporal scales by decade. Geomorphological research occurs at micro to macro scales (Table 2-1) and temporal periods of days to decades.

The evaluation of time in geomorphic analyses in crucial to the validity of any conclusions. As Schumm (1992, pp. 39) states, " the period of record must be adequate to describe the phenomena of concern." The length of time over which phenomena should be studied is not a simple deduction (Pilkey, 2003). Physical processes occur over a variety of time scales, and the time period used must be adequate to describe the process (Viles and Goudie, 2003). The temporal analysis of coastal evolution cannot be neatly divided into short and long-term components. Emphasis on large scale coastal behavior (LSCB) (Carter and Woodroffe, 1994is

needed to determine the extent of coastal evolution. Responses of the shorelines of the world would be simpler to evaluate if there were some "observable and straightforward explanation for most changes" (Carter and Woodroffe, 1994, pp. 2).

Table 2-1. Importance of scale in spatial and temporal research

Macro scale	Brown and McLachlan, 2002; Clark, 1976; Clark, 1997; Phillips, 1988; Phillips, 1997; Viles and Goudie, 2003; Viles and Spencer, 1995.
Micro scale	Abumere, 1980; Conway and Nordstrom, 2003; Gares, 1987; Nordstrom et al., 1999; Nordstrom et al., 2002; Sherman and Bauer, 1993.
Long Term	Carter, 1988; Dean, 1999; Dolan et al., 1991; Foster, 1992; Foster and Savage, 1989; Nordstrom, 1996; Pilkey, 2003; Schumm, 1991; Van Der Wal, 2004; Viles and Goudie, 2003.
More immediate	Byrnes et al., 1995; Dolan et al., 1991; Gares, 1990; Haggett et al., 1977; Phillips, 1997; Phillips, 2005; Schwartz, 1971; Shideler and Smith, 1984.
Multiple Causality	Butler And Walsh, 1998; Phillips, 2005; Phillips, 1997; Schwartz, 1971; Walsh et al., 1998.

Caution is important in extrapolating results before determining landscape behavior over time, because the landform may not be responding to a single input into the system. The importance of time in evaluating coastal systems cannot be overstated. In evaluating of coastal variables, selecting the wrong study period for the process can cause totally inaccurate results (Dean, 1999; Dolan et al., 1991; Foster, 1992; Foster and Savage, 1989). In Australia initial 4-week study of longshore drift (Schumm, 1992) produced results that were inconsistent with the local coastal features. By extending the study period, longshore drift in the opposite direction was also noted. Similarly Nordstrom (1994) notes that the historically multidirectional drift pattern along the coastline of New Jersey has been rendered unidirectional by the impacts of human development. Those studying the New Jersey coastline over short periods of time (not considering the pre-1935 shoreline) conclude that the drift system is to the south only, being unaware that the choice of time period influences the conclusions. Evaluation of the impacts and longevity of renourished shorelines requires extensive temporal investigation. Van Der Wal

(2004) used a 15-year horizon over which he evaluated the impact of renourishment on beach profiles of the Dutch coast.

This research considered the time period of accelerated coastal development in Florida. In St. Johns County access was not available to Anastasia Island until the 1950s (Olsen, 1974). The proposed period from 1972 to 1999 represents the timeframe for much of the development in the two counties (Figure 2-1) (Bodge and Savage, 1989; Brevard County, 1989; Long, 1968; St. Johns County, 1979, 1993, 2002; Toth, 1988). Impacts of physical characteristics on development can only be determined for time in which development had occurred. Beginning in the 1970s ensures that the baseline development already present was low density. Change in those areas, and the development of formerly vacant areas, will illustrate the impacts of the physical environment. Similarly the legislation requiring state-coordinated planning was initiated in 1972, and local comprehensive plans was required in 1975. This importance of land use controls on settlement patterns along the coast is discussed later in this section.

The importance of time lag should also be mentioned, particularly because response in the coastal zone is not necessarily linear. Any analysis of the coast should consider lagged effects. In longshore drift, the impact of jetties, for example, is not immediate (Nordstrom, 1996; U. S. Army Corps of Engineers, 1993). A cyclical pattern of shoreline positions over time, analyzed using a linear regression, may appear stable (Nordstrom, 1994). The use of the dynamic geomorphology variables, described in the methodology will address these issues.

Few processes or landforms in geomorphology are isolated in space. It is important to consider each research area part of a complex spatial system. Findings from one scale cannot necessarily be extrapolated, because with increased scale, there is increased complexity in the system. Conclusions about specific landforms cannot be extended to others that appear similar, but vary in size (Phillips, 1988; Phillips, 1997). Haggett and others (1977) describe the scales of geographic inquiry and suggest caution when inferring characteristics from one level to another. This research used the same scale, spacing, and frequency of data for both study areas.

Scale of investigation is as important as time period when analyzing of the coastal environment. A small portion of a barrier island cannot be considered in isolation, any more than a single barrier island can be considered without those adjacent to it (Schwartz, 1971; Shideler and Smith 1984). Davis (1997) showed varied in shoreline dynamics along the Gulf of Mexico coast. If only a small portion was considered the extrapolated results would have been erroneous. Dolan and others (1991) showed the need to consider erosion rates when selecting an area. Gares (1990) considered the whole coast of New Jersey, rather than a small area. This research was used to mitigated conclusions about specific areas that may have been generalized or too specific.

Many of the geomorphic data used in this research are secondary, collected by the State of Florida, and the importance of field evaluation cannot be underestimated (Lucas 1996). Aerial photography and field verification are crucial to understanding local dynamics not reflected in mere data analyses (Foster and Savage, 1989). The use of secondary data necessitates vigilance. Users must investigate the suitability of the data for the interpretations made. In this research the secondary data are considered robust because the organization that compiles the data (the Florida Department of Community Affairs) is constant over time. Variation in data by local jurisdiction is one factor affecting local responses to geomorphology; this variation may be an appealing dynamic of the research.

Techniques and Data; GIS and Aerial Photography

Geographic Information Systems (GIS) are "tools that enhance and broaden the opportunities of geomorphology and together with field studies offer a robust synergistic design to explore a host of research questions associated with landscape characterization and the linkage of scale, pattern and process" (Butler and Walsh, 1998, pp. 179.) GIS can be used to assess landscape units spatially, to evaluate geomorphic patterns and spatial interactions, and to illustrate spatial relationships among variables (Kriesel and Harvard, 2001). GIS coverages incorporating remotely sensed and aerial data have expanded the geographic capacity for analyses in both spatial and temporal contexts. Lucas (1996) describes coastal data as being "four dimensional:"

with components of length, width, height/depth and time. GIS has expanded the potential for evaluating "landscape conditions through the interrelationship of scale, pattern and process" (Walsh et al., 1998, pp. 183). However, GIS techniques should not be used in isolation without the integration of fieldwork (Walsh et al., 1998). GIS has traditionally been used to illustrate spatial relationships. This research used temporal and spatial data to analyze relationships among the planned and built environment and the geomorphic characteristics of the coast.

An important aspect of GIS in geomorphology is the ability to show topography. The coastal domain of Florida, however, has no extreme (elevations ranging from 0 to 10 meters). El-Raey and Nasr (1996) also note the difficulty of vertical or "z "scale in low-lying coastal areas and the difficulty of interpolating topography information for use on coastal scales with low "z" values. GIS was used to evaluate the relationship of the human variables, land-cover, and topography. El-Raey and Nasr (1996) used an average elevation for each land-cover category in an attempt to quantify losses due to sea-level rise. In this research dune height represents the topographic measure. GIS have practical applications in addition to its importance in coastal research. In New Jersey investment in GIS were crucial to the coordination of coastal zone management (Neuman, 1999). The State Planning Commission was funded to use GIS in a multi-agency level dialogue, with input from state and local agencies, citizens and private interests.

A crucial aspect of using GIS in spatial and temporal research is its ability to use a wide variety of data types, such as maps, aerial, or remotely sensed images, survey data, and land use coverages. This research has some limitations for GIS applications. The research data comprise points and lines in vector form. Each data transect is separate in space. Interpolation of the characteristics of the shore-normal profile from one area to the next is possible, using one of the many methods of interpolation. The combination of types of planform and profile data allow the user to produce a three-dimensional representation of the shoreline. Coastal research could

produce cell coverages suitable for raster manipulation. However, the spacing of these data (more than 300m apart) is not conducive to interpolation.

Information sources for investigating coastal changes in planform include navigational maps, USGS 1:24,000 topographic maps, NOS "t" sheets, aerial photography, and remotely sensed images. Spatially using aerial photography is one way to evaluate the coast (Table 2-2). However, caution is needed when interpreting data. Theiler and Danforth (1994) give a comprehensive methodology for preparing a control network, resolving distortions and inaccuracies, before inputting the information into a mapping program. Other considerations in evaluating of data accuracy are map shrinkage, defects, projection, and age (Crowell et al., 1999). The age of the photography, tilt, relief displacement, radial lens distortion, position of the tidal datum, fiduciary points (known points on overlapping photographs), photograph overlap and control points available for triangulation, film buckling, humidity, and type of paper, must all be considered in assessing the accuracy of the aerial photography (Theiler and Danforth, 1994).

GIS has increasingly been used in conjunction with aerial photography in coastal areas. The scales of coverages and extent of coastline investigated vary from individual dune systems to broad analyses of entire coastal reaches. Bush and others (1999) consider aerial photography suitable for coastal evaluation at the regional, local and site-specific scale. El-Raey and Nasr (1996) used 1:25,000 scale photography for regional evaluations and 1:2000 photographs on a local scale to investigate the impacts of sea-level rise on land use, population and land value along the north coast of Egypt. Stanczuk (1975) used aerial photography with profile data to evaluate the impacts of development of coastal characteristics.

Aerial photography has been used in coastal areas to show changes over time (Carter and Woodroffe, 1994; Hails, 1977). Nordstrom evaluated the effects of engineering structures on four inlets in New Jersey, and determined the planform changes over time. He found that a formerly unidirectional drift system had been altered, and that shoreline mobility had been reduced after 1935. Two areas of rapidly expanding urbanization along the Australian coast were evaluated to

determine the sequence of development between 1947 and 1994 (Essex and Brown, 1997). Originally low-density development spread along the coastal strip (suburban style) in the 1980s. Photography was combined with planning documentation and field evaluations.

Table 2-2. Use of aerial photography in coastal geomorphology

Geomorphic changes	Crowell et al., 1999; Davis, 1997; Dean and Malakar, 1999; Dolan et al., 1991; Kaufman and Pilkey, 1983; Stanczuk, 1975; Theiler and Danforth, 1992.
Human impacts	Carter and Woodroffe, 1994; Hails, 1977; Nordstrom, 1996; Essex and Brown, 1997; Dean and Donohue, 1998
Measurement of urbanization	El-Raey and Nasr, 1996; Essex and Brown, 1997; Hart, 2000;Vernberg et al., 1996.

Beach Profiles and Applicability

Beach profile data may be used for various purposes, from descriptive (Stone et al., 1985; Stone and Salmon, 1988) to highly quantitative analyses (Chiu, 1986; Guan-Hong et al., 1995; Hesp, 1988). The profile shape and form indicates the stability of the coastal area and its potential suitability for development. Combining aerial photography and beach profiles provides a valuable combination of cross-sectional and planform perspectives (Al Bakri, 1996; Stanczuk, 1975; Wright, 1991). The stability of the beach profile depends on wave and wind conditions, sediment size and beach slope, in the short term; and depends on sea level, sediment supply, littoral transport, and storm frequency in the long term (Reesman, 1994). Table 2-3 shows the geomorphic and human variables evaluated as components of beach profile characteristics.

Beach profile data have been used to evaluate the impacts of human changes to the coast at various scales. Wright's (1991) work at the large scale (spanning the states of New Jersey, North Carolina and South Carolina) measured the dry beach width from surveyed profiles and used it as a proxy for the portion of the beach that is continuously available for recreational use. It quantified the value society puts on the recreational amenity, and used dry beach width to compare the impacts of stabilized shorelines. He determined that the dry beach width was

consistently narrower where the shore was stabilized, except where groins and renourishment occurred.

Stanczuk (1975), Al Bakri (1996), Bush and others (1999), and Rahn (2001) evaluated the influence of development on beach profile changes at smaller scales. Stanczuk (1975) evaluated 36 profiles over a 4-month period on Bogue Banks, North Carolina. He noted that on a small scale developed areas updrift prevented sediment movement, caused changes in profile width and gradient, and prevented the profile from recovering from the impacts of seasonal changes and storms. Bush and others (1999) used beach width, slope, and elevation derived from profile data to develop qualitative geoindicators. These indicators were expanded for use along the North Carolina coast for risk assessment and hazard mitigation. Rahn (2001) compared the beach profiles in developed and undeveloped sites in two areas of the Florida panhandle.

The major shortcomings of beach profile data are the spatial and temporal frequency of data collection. Temporal frequency is a concern because of the dynamic nature of the coast. Profile data give specific information only for the time period during which they were collected. The data provide no indication of historical or seasonal changes, nor can they be used to predict the future (Stanczuk, 1975). The beach profiles Stanczuk's study are a snapshot of the beach morphology at a specific time. This is a problem because beach profiles are extremely dynamic and sensitive to storm or seasonal conditions. Similarly the coarse scale alongshore will not reflect a continuous surface. The data cannot be used to interpolation shore-normal topography at this scale. The individual profiles are used in conjunction with development variables recorded in the adjacent sample areas at the transect. Using profile data over the study period to determine dynamic geomorphology variables reduces the influence of outlying values. The Department of Environmental Protection conducts data collection for evaluating beach conditions during the fall and spring, at times when storm activity has been minimal.

Seasonal variations reflected in the profile data taken at different times of year may also lead to inconsistencies or errors. Wright (1991) used dry-beach width during summer, to

minimize the effect of storm influences. Seasonal variations include profile shape, which may vary significantly in winter months when high wave energy may cause the development of longshore bars with sediment that would otherwise be part of the terrestrial profile (Foster and Savage, 1989). The prevailing philosophy is that winter waves denude (and summer waves restore) the beach profile in a natural system (Carter, 1988; Guan-Hong et al., 1995). Al Bakri (1996) analyzed beach profiles in Kuwait and noted the tendency for the profile volume to increase in summer and decrease in winter. The volume of material in the profile is not used as a variable in this research. It was considered that the volume varies seasonally on shorter timeframes than data by decade can reflect. The profile data timescales were considered too coarse to provide a useful measure of volume. Additionally, Rahn (2001) found no relationships between subaerial volume variations in developed or undeveloped areas.

Table 2-3. Beach-profile research; geomorphic and human variables

Variable	Study
Beach width	Clark, 1999; Rahn, 2001; Shideler and Smith, 1984; Stanczuk, 1975; Wright, 1991.
Dune height	Gares, 1987; Nordstrom et al., 1990; Rahn, 2001; Shideler and Smith, 1984; Stanczuk, 1975.
Profile gradient	Allen, 1991: Meesenburg, 1996.
Position of dune crest	Allen, 1991; Gares, 1987; Olivier and Garland, 3003; Rahn, 2001; Stanczuk, 1975.
Profile volume	Al Bakri, 1996; Allen, 1991; Gares, 1987; Rahn, 2001.
Barrier island width	Stanczuk, 1975; Stone et al., 1985; Stone and Salmon, 1988.
Impacts of erosion and flooding	Balsillie, 1985; Clark, 1999; Dean and Malakar, 1999; Fenster and Dolan, 1996; Gares, 1990.
Seasonality	Dolan, 1976; Stanczuk, 1975.
Storms	Webb et al., 1997; Meesenburg, 1996.
Long-term shoreline change	Bodge, 1992; Foster, 1992; Foster, 2002; Foster et al., 1989; Foster at al., 2000; Olsen, 2003.
Human data	Bellomo et al., 1999; Finkl and Charlier, 2003; Foster, 1992; Foster et al., 1989;
Coastal Development	Al Bakri, 1996; Bush et al., 1999; Rahn, 2001; Smith, 1994; Stanczuk, 1975.
Foredune grading	Hails, 1977.
Sand mining	Carter, 1988; Davis and Barnard, 2000; Hails, 1977.
Structures	Collier et al., 1977
Vehicular traffic, trampling, vegetation, and fences	Carter, 1988; Viles and Spencer, 1995.

Dolan (1976) considers seasonal beach profile variations are of minor significance because the change is confined to the shoreface. Unless significant winter storms breach the primary dune, the area of wave runup is the dynamic portion of the profile, constrained by the first topographic berm structure. During high-energy storms, erosion will cause the beach width to increase providing a larger area over which wave energy can dissipate. A barrier island with no obstructions to sediment transference can withstand periodic storms (Meesenburg, 1996). Another shortcoming of profile data is that the profile may not extend far enough to incorporate all aspects of the sediment budget. Sediment loss from aeolian forces that extend inland beyond the profile will not be accounted for. Similarly sediment that is transported beyond the beach face offshore may be considered lost to the system.

Population and the Coast

Having established the physical environment in which this research occurs, it is important to review the policy direction and ultimate development of the human environment in coastal reaches. Fifty percent of the world's population lives within 1 kilometer of the coast (Goldberg, 1994), 75 percent of the United States population lives within one hour's drive of the coast and in Florida 80 percent of the population lives in the coastal counties (Finkl, 1996). Coastal counties comprise 20 percent of the nation's land area, contain almost half the population and by 2010 will contain more than 127 million people (H. John Heinz Center, 2000). Lins (1980) determined that even in the mid 1970's 37 percent of the Atlantic and Gulf coasts of the Untied States contained development and by 1983 741 kilometers or approximately 63 percent of the Florida coastline was developed (U. S. Department of Interior, 1983).

Patterns of development are measures of spatial arrangement. Locations with the same population density may not have the same spatial arrangement of land uses (Vernberg et al., 1996). The distinction between the size, nature, and arrangement of settlements and the specific pattern of the community is important. The location of a community in relation to the environment, and on a smaller level, the specific layout of a community, represents spatial

patterns at contrasting scales. This work concentrates on the influence of geomorphology on the "macrosettlement" or location within the confines of the physical environment.

In coastal areas settlement patterns do not necessarily conform to established settlement norms. The physical environment and transportation access supplies a set of limitations or controls. Coastal development of barrier beaches reflects a recognized style that is limited by topography (Kostof, 1991). Montreal has a linear pattern determined by the location of the river and Reps (1965, pp. 68) states "the general form of this city – a narrow linear pattern – was strongly influenced by topography." Coastal development is similarly influenced by topography and patterns also conform to the linear pattern recognized by Reps.

Contemporary Coastal Settlement Patterns

Spatial patterns are particularly relevant in coastal areas because although population densities may not be increasing, urbanization of land is occurring (Davidson-Arnott and Kreutzwiser, 1985). The transition from industrial to post-industrial cities, and from modernism to post-modernism has caused urban form to decentralize. Polynucleated areas with amorphous suburbs have eclipsed the former metropolitan concentrations driven by industrial growth. Distinct patterns of tourist-driven growth have been identified (Meyer-Arendt, 1990)

Vernberg and others (1996) identify the predominant pattern of coastal development in the southeastern United States to be urban concentrations with adjacent low-density areas. The population density of an area many not change even when the settlement patterns vary. Over the last 30 years the number of metropolitan areas nationally has increased, while the average density has decreased (Vernberg et al., 1996). A study of coastal counties in the southeastern United States using aerial photography and satellite images showed that sparsely populated counties were becoming populated with low density residential developments (Vernberg et al., 1996). Thus, more land is consumed and the urban area expands without a change in the population density. In coastal areas, the segments of population that are expanding most rapidly are whites and the elderly (Vernberg et al., 1996). Vernberg states "low-density residential use along the shoreline

is occurring as small family units of older people having large lots and second home commuters from the nearby metropolitan areas" (pp. 11). Similarly, along the north coast of new South Wales, Australia, 35 percent of second homebuyers purchased homes for retirement destinations (Essex and Brown, 1997).

The economic prosperity of the late 1990's and the new century has contributed to residential development and the second home market in coastal areas (Overberg, 2000). However, research in Australia indicates that the economy may not be the most important factor in coastal location. Walmsley and others (1998) found that "pull" factors, such as the physical environment, climate and lifestyle influence development more than "push" factors, such as employment prospects and salaries. Polling 150 households that moved to the north coast of New South Wales, he concluded that migrants to the coast were influenced by image and quality of life, rather than employment opportunities, pay and working conditions.

Legislated Incentives for Development

Development of Florida's barrier islands has been as a result of the interaction of many forces. A measure of the importance of the physical amenity of the coastal zone, available access, local restrictions or incentives is captured in this research, while Federal and State tax advantages are not. In this research the influence of politics in the study area, or at county level and the State and National level are also a component of what is reflected in the settlement patterns. The influence of legislation as an incentive or disincentive for development on the coast is likely to be equally if not more important, than the physical characteristics.

Several provisions in the Federal tax code have influenced coastal residential development (Beatley et al, 1994). Deductions for home mortgages on personal income tax returns were intended to assist home ownership. Second home mortgages can also be deducted providing additional tax incentives for those affluent enough to afford them. The use of residences for a commercial enterprise, such as rental property is also subsidized by the tax code (Thom, 2004). Losses incurred for lack of rental income, or deductions to improve the property are permitted.

Individuals can therefore purchase or construct residences, speculate on rental income, and use them as tax deductions if they are unsuccessful. Revisions to the federal tax code permitting the one-time exemption of capital gains for homeowners over 55 may have also encouraged retirees to relocate to coastal areas (Vernberg et al., 1996).

The National Flood Insurance Program was enacted by tbe National Flood Insurance Act (Table 2-4) of 1968 (Von der Osten, 1993) provides flood insurance to property owners in areas where the local government has adopted and enforces floodplain management standards to reduce potential flood damage (Bellomo et al., 1999). Local governments may use zoning restrictions, subdivision regulations, building code compliance and minimum elevations to mitigate potential flood damage. Although it has been argued that the restrictions required to be adopted by local governments to participate in the NFIP increase the cost of development in the coastal zone, the availability of flood insurance serves to enable development that would otherwise be too costly to insure (Von der Osten, 1993). In Florida, insurance under the National Flood Insurance Program is a requirement for eligibility to request public disaster assistance funds (South Florida Regional Planning Council, 1989)

The Coastal Construction Control Line (CCCL) is set to reduce the potential for structural damage and beach erosion (Von der Osten, 1993). The CCCL are adopted on a county-by-county basis, and state permits are required from the Florida Department of Environmental Protection (DEP) for construction or excavation seaward of the line. The line is calculated by elevation in relation to storm and hurricane tides, predicted maximum wave up rush, contours (including offshore), vegetation, erosion trends, dune line, and existing development. There are also exemptions to permits, most relevant to this research are the structures completed before the establishment of the first line in 1972 (Von der Osten, 1993). Any changes to structures must be contained within the original footprint. Structures that are justified to DEP and seaward of the CCCL must be designed to withstand a 100-year storm event, wind velocity of 95.5 km/hr. Structures must also be elevated above the calculated breaking wave crests or wave uprush of a

100-year storm and anchored to a pile foundation. Excavation seaward of the CCCL is not recommended but may be permitted.

Table 2-4. Coastal and growth management legislation that impacts the Florida coast

Year	Name	Legislation
1968 (Federal)	The National Flood Insurance Act	Insures structures from hazards with backing of the Federal Government
1972 (State)	The Coastal Construction Control Line (CCCL)	Established to reduce the potential for structural damage and beach erosion
1972 (State)	State Comprehensive Planning Act	First Statewide growth management legislation
1972 (Federal)	Coastal Zone Management Act	Establishment of national coastal management coordination and funding for State coastal program
1974 (Federal)	The Disaster Relief Act	Federal disaster assistance administered by the Federal Emergency Management Agency.
1978 (State)	The Florida Coastal Zone Management Act	Resolution of conflicts between agencies concerning coastal land and water
1982 (Federal)	The Coastal Barrier Resources Act (CBRA)	Prohibits federal assistance on designated undeveloped coastal barriers that comprise the Coastal Barrier Resource System
1985 (State)	The Florida Coastal Zone Protection Act	Building regulations in coastal areas. Structures must be designed to withstand 100-year storm wind speeds and erosion impacts.
1985 (State)	Local Government Comp. Planning and Land Development Regulation Act	Requires Florida cities and counties to develop comprehensive plans and land development regulations
1991 (State)	Florida Beach and Shore Preservation Act	Requires all construction, reconstruction or shoreline protection to have a coastal construction permit from DEP with a 15.25m setback line from mean high water, the average high of high waters over 18 years.
1999 (State)	The Coastal Construction Control Line (CCCL)	Authority of individual counties to permit structures and erosion controls

Sources: Bellomo et al., 1999; South Florida Regional Planning Council, 1989; Vernberg et al., 1996; Von der Osten, 1993

As noted in Table 2-4 the Coastal Barrier Resources Act (CBRA) prohibits federal assistance on designated undeveloped coastal barriers that comprise the Coastal Barrier Resource System. Private property rights are still in effect and development can occur, but without Federal subsidies for transportation networks, and flood insurance. Existing jetties and channels, road

repair and the operation, maintenance and construction of military facilities are exempted. In Southern Brevard County between monuments 157 and 164 there is a CBRA designated area.

Coastal management at all levels is complicated by the conflicting mandates of the various agencies. Nationally the Corps of Engineers permits dredge and fill and coastal structures, while the Environmental Protection Agency protects wetlands. Neuman (1999) illustrates the complications using an example of barrier island bridge construction. The construction may be warranted by traffic counts by the Department of Transportation, encouraged by tourism goals of the Department of Commerce and the local jurisdiction, and permitted for construction by the Corps of Engineers. The Department of Environmental Protection may deny the project because of endangered species protection. States have a variety of ways of controlling the coastal zone, while remaining consistent with the Coastal Zone Management Act. North Carolina and California have Commissions authorized to enact coastal legislation. New Jersey manages the coast through the executive branch and uses a process of "cross acceptance" (Neuman, 1999). Coastal zone management is integrated so that planners, politicians, academics, and citizens develop policy collaboratively. Regional programs, such as for the Chesapeake Bay are also used to manage specific resources.

In Florida, as in many other states and at the Federal level, coastal zone management is decentralized. In 1992 the Department of Community Affairs, created a Coastal Zone Management Office within the Secretary's Office. This was to address "the "fringe" nature of coastal management in the realm of state government" (Bernd-Cohen et al., 1993, pp. 41). Previously the Florida Coastal Management Program had been located in Department of Environmental Protection (Bernd-Cohen et al., 1993). The State Department of Community Affairs is the Department charged with land use and resource planning and enforcement of the State's growth management plan. The move realigned coastal management in Florida with the policy, land use and development activities, rather than environmental and data collection functions of the Department of Environmental Protection. In this way the enforcement of growth

management could be extended to coastal issues. Coordination of multi-jurisdictional coastal issues, or the designation under the Areas of Critical State Concern legislation (Tin, 1976) can be facilitated at the state level.

Land use authority in Florida is delegated to the County and municipal level and as a consequence interactions between development and the coast occur at the local level. In this way the use of county jurisdictional boundaries makes sense for the human variables. "Although much federal and state legislation has been enacted to assist the management and regulation of coastal development and redevelopment, local government regulatory tools and programs provide the most significant opportunities…" (South Florida Regional Planning Council, 1989, pp. 65).

In Florida, homestead exemption, which exempts the first $25,000 of value from ad valorem taxation, is available for primary residences. In rare cases, such as mobile homes on small lots with taxable values of less than $25,000, there is no assessment of taxes. In the past, before appreciation of the value of coastal property this form of development was prevalent to northeast Florida. In St. Johns County the changes in land use from the 1970's to the 1980's shows several examples of trailer park conversions to large commercial endeavors. In 1997 the Save Our Homes Amendment was enacted. This amendment has important attributes that impact residential development, particularly in coastal areas. The constitution of the State of Florida was amended after residents in southwest Florida objected to rapid property tax increases as coastal property appreciated. Statewide, property that is owner occupied and with residents claiming a homestead exemption, is limited to 3 percent increases in ad valorem taxes annually. When property transactions occur the residual property taxes are levied. This has made analyses of taxable value as an indicator of property appreciation inappropriate.

Land Use Planning in Florida

Settlement patterns are influenced by the market and government regulations, such as zoning, transportation and tax policy. Growth management legislation throughout the country struggles with the degree to which public policy should restrict the free market through land use

(Hart, 2000). The value of a parcel of land may be reduced by environmental restrictions, for example. The recognition that coastal areas are highly desirable for development forces local jurisdictions to address the competing needs of development pressures, preservation of traditional uses (such as fishing), protection of the environment, and maintenance of the coast for public recreational use. Such delegated authority to the local level has inherent problems. Each proposal is reviewed individually and the cumulative impacts of coastal development may be overlooked.

Managing growth in Florida has been a dilemma since the introduction air conditioning, the Space Program in Brevard County and the selection of Florida by the Disney Corporation for the location of their second theme park. In 1972 the first requirements for comprehensive planning were enacted by the Legislature in the State Comprehensive Planning Act. In 1985 the Local Government Comprehensive Planning and Land Development Regulation Act (Chapter 163, Florida Statues) specified the requirements of Florida cities and counties to develop comprehensive plans and land development regulations. These plans had requirements specific to the coast, such as protection of coastal resources, control of water dependent uses, limiting of developments in high hazard areas and the provision of public access (South Florida Regional Planning Council, 1989). Section 9J-5 of the Florida Administrative Code specifies the minimum criteria for coastal zone management elements of the comprehensive plan. Communities must inventory, analyze and project the impacts of future land use and its impact on hurricane evacuation. Each local jurisdiction must develop post-disaster plans for high hazard areas and attempt to minimize future exposure of development, infrastructure and individuals to coastal hazards.

Determinations of countywide existing and future land use designations, by local jurisdictions were required after the 1972 State Comprehensive Planning Act and the 1985 Local Government Comprehensive Planning and Land Development Regulation Act. The first Comprehensive Plan submitted to the Department of Community Affairs under the 1985

requirements was made by Brevard County in 1988. Each Comprehensive Plan must be updated every 10 years. Therefore, the study areas have plans from three time periods, the 1970's, late 1980's and late 1990's. Each plan delimits the existing last use and proposed future land use restrictions at a parcel level. Use of parcel data provides the ability to use detailed information and to combine it to consider cumulative impacts on the coast (Hart, 2000). The public policy of the local jurisdiction, illustrated by the existing adopted future land use restrictions are investigated in this research.

Research Hypotheses

Schumm (1991) uses examples to illustrate the potential errors that can be made when attempting to extrapolate from the present to the future, or past in earth sciences. Schumm maintains that the use of multiple hypotheses will eliminate problems with interpretation of natural systems. He notes multiple hypotheses assist with "specific procedural problems that may be encountered in the development of explanations of phenomena and the extrapolation of research finding to analogous and homologous situations" (Schumm, 1992, pp. 34). There are four main hypotheses investigated in this research.

Hypothesis 1: Local geomorphology at each time interval impacts human variables at the same interval

Hypothesis 1a: The local geomorphology influences the actual development. This hypothesis is illustrated by a relationship between actual geomorphology, and the human variables at that time (Conway and Nordstrom, 2003). An example of this is the impact of the beach width on the number of units. A wider beach indicates a more stable coastal area that may be suitable for more units, than an area with a narrow foreshore.

Hypothesis 1b: The local geomorphology influences the land use control decision-making. This hypothesis proposes that future land use plans are developed by considering geomorphological conditions, such as the suitability of land use for development noted by Hails (1977). An example of this hypothesis is an area with large dunes being designated as suitable

for higher adopted future land use densities, so the higher the maximum dune height, the higher the proposed number of units permitted in the future planning horizon.

Hypothesis 2: The dynamic geomorphology impacts human variables

Hypothesis 2a: The dynamic geomorphology indicators influence the actual human variables. A dune height that varied over decades indicating dynamic local coastal geomorphology would be negatively correlated to human variables such as the number of dwelling units and impervious area. The more height variation the more dynamic the environment and the less suitable it is for development. Thus the area would have a lower the number of units, and smaller impervious areas indicating that the physical environment had impacted the development characteristics. Lundberg and Handegard (1996) noted the adaptation of agricultural uses to the environment, and McMichael (1977) and Miller (1980) noted the preference of higher ground inland of the barrier island for settlement.

Hypothesis 2b: The dynamic geomorphology indicators influence the land use control decision-making. An example of this hypothesis is a beach width changed over time in any direction that would indicate a dynamic coastal area. Such an area would not be suitable for the establishment of high proposed future land use densities. The more beach width increased and decreased over time the less suitable the area for development. Thus the area should have a lower planned future land use density. Bush et al., (1999) detail zoning restrictions used for hazard mitigation in North Carolina. This hypothesis proposes the reverse, with zoning outcomes as the result of the characteristics of the physical environment.

Hypothesis 3: There are temporally lagged relationships between the actual and dynamic geomorphology variables and the human variables. This hypothesis contemplates that geomorphology in one time period will influence human variables in later time periods. For example, the wider the beach width the more stable the coastal environment and therefore the more suitable for greater impervious area percentage in the later time period. Nordstrom (1987) noted that the impact of jetties on the coastal system was delayed and could not be evaluated on

an immediate timescale without inaccurate conclusions. Van Der Wal (2004) used a 15-year evaluation of renourishment to determine delayed impacts of the activity.

Hypothesis 4: The dependent variables will have different relationships with the independent variables in the two separate study areas.

The explanatory power of the individual variables will be different in each county. For example, the influence of the shoreline orientation, drift direction and storm history in each county will make the local geomorphology less significant due to the larger scale and longer-term impacts. The regression coefficients and significant variables for each county will be different. Schwartz (1971) and Shideler and Smith (1984) show that areas cannot be evaluated without those adjacent. In this research the two counties are not adjacent, and governed by different policy-making bodies. Thus conclusions about the two counties are likely to be dissimilar. Davis (1997) used research along the Gulf of Mexico coast and demonstrated the alongshore variability.

CHAPTER 3
STUDY AREA

The two areas investigated are long inhabited and historically significant. Brevard County was originally an important agricultural area and large producer of citrus crops. The coastal development was initiated in the 1940's and boosted by the choice of the Cape Canaveral area for the location of the National Aeronautic and Space Administration (NASA) facilities. The areas are characterized by low-density development and incorporate a mix of single family homes, multi-family condominia and commercial areas that were settled predominantly in the last thirty to fifty years. Allen (1991) considers the Brevard County and adjacent areas the least intensively studied in Florida. The northeast Florida region contains St. Augustine, the longest inhabited city in the United States (Fernald and Purdum, 1992). Human habitation has continued from the rule of the Spanish to the recently developed golf course communities of the Ponte Vedra area. Both Brevard and St. Johns counties are located on the east coast of Florida, and although separated by the false cape of the Cape Canaveral National seashore, a similar orientation to winds, waves and tides exists from Nassau County to Jupiter Inlet. The two study areas are in this area and exist with similar large-scale geomorphic conditions.

> The story of South Florida's evolution from a crocodile and mosquito infested swamp to a sybarites Shangri-la by the 1950s is a story of ambition, hype, and technological wizardry pressed into service for the pleasure principle – the saga of creating paradise from silt and scratch. Lencek and Bosker, 1998, pp. 234.

In 1907 yellow fever was eradicated, providing a milestone for the colonization of Florida. In 1927 the density of Florida was 1 person per 10 ha (Florida Department of Agriculture, 1928). Large population centers at that time were Orlando, Jacksonville, Pensacola, Tampa and Miami. The coast was considered a resource for the function of ports. Many of the settlements, accessible only by water had origins as fishing villages. However, Tampa and Miami had their

origins in the export of citrus products. St. Augustine was a minor port. The channel and harbor in St. Augustine were reported to be 1.8 to 2.4 m deep. Cape Canaveral was predicted to become a port of importance because of rail connections, the protection afforded and the piers and availability of land for terminals. Agriculture, forestry and expansion of the cement and fruit exporting industries were identified as the goals for the future of Florida (Florida Department of Agriculture, 1928).

The main attractions of Florida were described as climate and scenery (Florida Department of Agriculture, 1928). Tourism was identified in terms of hunting and fishing, ironically only for men. One of the unique features of the state was identified as the beaches. They were considered unique because they contained rare metallic minerals. The fact that beaches were flat and hard and suitable for vehicular traffic was recognized as a novelty. The indication that a small number of coastal areas had made preparations for tourism at in the 1920's was illustrated through the increase in hotels and rooming houses and the number of golf courses. It was recognized that "winter visitors will come here, and in gradually increasing numbers" (Florida Department of Agriculture, 1928, pp. 161). In contrast, in 1981 eighty six percent of tourists visiting Florida participated in coastal-related activities (South Florida Regional Planning Council, 1989).

Geomorphological Characteristics of the Florida Coast and Study Area

Beaches and sand dunes are vital for tourism and recreation in Florida. These areas are also vital for dissipation of wave energy, protection from coastal storms and storage of sediments. The coastline of Florida varies from narrow sandy spits to coral reefs, and from remote wildlife sanctuaries to thriving urban areas. The 1,900 km of coastline in Florida is the longest in the coterminous United States. Florida's wide continental shelf, sediment supply and wave energy contribute to a coastline fringed with barrier islands and tidal inlets. The area inland of the barrier island, is composed of tidal lagoons, linked together, and deepened by dredging to form a navigable route, the intracoastal waterway, around the entire state. There are 1,250 km of sandy

beaches in Florida (Foster, 1992) representing over 25 percent of the sandy shores in the United States (Morgan and Stone, 1985).

The most dominant feature along Florida coast is the presence of barrier islands (Davis et al., 1992). Pilkey and Dixon (1996) identify four conditions that must exist for barrier island formation. These are sea level rise, gently sloping coasts, a source of sediment, and a wave regime suitable for transporting sand. The favorable factors for barrier island development are present in Florida and explain the dominance this feature. The only areas of Florida that do not have barrier islands are the Florida Keys and the Big Bend area (Figure 2-1), which lacks sufficient wave energy and an adequate sediment supply (Lannon and Mossa, 1997).

Barrier Islands

Barrier island shapes are determined by coastal conditions. The coast of Florida has been classified from moderate to zero energy environments (Tanner, 1960), and the study areas are microtidal (Davis and Fox, 1980; Davis, 1994; Davis 1997). Typical of microtidal wave dominated conditions, the barriers are long and narrow with few inlets and have smooth uninterrupted shorelines. Inlets are traditionally unstable with large flood deltas and are prone to migration and closure if not stabilized. Dunes, and in areas that are prograding, dune ridges, are usually present (Davis, 1994a). The barrier island system of Florida has developed in the last 3000 years (Davis, 1994b). Florida was a large carbonate platform covered with shallow seas 100 million years ago. Sediments from the southern Appalachians were carried along both coasts of Florida during the Pleistocene. There are minimal terrigeous sediments entering the system and the sediment from rivers is trapped within estuaries. Therefore, barrier islands are formed from the reworking of old sediments enabled by the slow rate of sea level rise.

Sea level rise during the Holocene, along with wave and tide climates influenced the formation of barrier islands. Sea level rise has continued from 15 to 18,000 BP to present. The rise was most rapid until 7,000 BP, when the rate slowed. There are a variety of scenarios proposed on sea level rise rates, and the rate and change in sea level rise is dependent on

geographic area (Aubrey, 1993). For the past 3,000 years the rates have varied with some authors favoring fluctuations while others recognize a steady rise in sea level (French et al., 1995; Pirkle et al., 1970). It is generally accepted that sea level rise over the last 3,000 years has been between 1 and 5 mm annually (Davis, 1994a).

There are two theories that dominate research on barrier island formation (Field and Duane, 1975). The coastal barrier beach of St. Johns County, north of St. Augustine inlet is a spit extension. Gilbert (1885) and Fisher (1968) contend that spits, or thin strips of sediment, extend from headlands in the direction of prevailing longshore drift. As sediment is pushed along the coast by wave energy it elongates into spits that may eventually become detached if sediment supply slows or if they are breached by storm waves. The detached spits will become vegetated trapping additional sediment, building dune systems and stabilizing a barrier island. Anastasia Island in St. Johns County is described as a barrier beach (FDEP, 2004a) and has several alternative theories of origin. Otvos (1970) favors the notion of emergence of shoals from underwater. There is some evidence that this occurs along the low energy Gulf Coast of Florida, but is unlikely to be responsible in other cases, such as Anastasia Island or in Brevard County. High wave energies along the eastern United States, for example, make it difficult to imagine how this process would form barrier islands under those conditions.

Transgression, or drowning in-situ (Hoyt, 1967) hypothesizes that coastal ridges or sand dunes formed, and were flooded as sea level rose after glacial melting. The ridges of sediment then move onshore as sea level rises producing a lagoon behind the sediment. It seems unlikely that any one theory is completely applicable for all conditions. The prevailing theory of barrier island formation is multiple causality, or many causes that may be inter-related (Schwartz, 1971). In parts of Florida, such as the Brevard County there are two series of barriers further suggesting multiple causality. The earlier barrier is the Merritt Island system, which is fronted by the current barrier islands and separated by Mosquito Lagoon, Banana River and Indian River Lagoon. This series reflects two transgressions of sea level. However, the Brevard County barrier system is

also unusual near the False Cape area, where a clear inflection point occurs. The barriers in the Brevard County areas have been classified as perched by Tanner (1960). That means that the sediment that is at the surface covers an original barrier from a previous geologic age.

Sediments

Coastal sediments in Florida are composed of quartz and calcium carbonate. The calcium carbonate is from shell fragments and oolite, or granular limestone grains (Johnson and Barbour, 1990). On the Atlantic Coast of Florida the amount of shell fragments, derived from coquina, or rock formed from shells, increases towards south Florida. The calcium carbonate volume increases from less than 10 percent in the Jacksonville area, to over 40 percent in Miami (Giles and Pilkey, 1965). However, the areas of central Atlantic Florida have also been found to have sediment variations. Sediment in Brevard County is described as having a composite mean grain size between 0.13 to 0.25mm, and 0.19 mm on average (U. S. Army Corps of Engineers, 1992). Stapor and May (1982) found that Jacksonville Beach, Anastasia Island, and False Cape, in Brevard County are composed of fine grained quartz sand, compared to the coarser sand with larger amounts of shell material in the intervening areas (Buckingham and Olsen, 1989). Foster et al. (2000) describe the sediment north of St. Augustine Inlet and south of Matanzas Inlet as "crushed shell hash," the source of which is nearshore coquina rock. The source of the noncalcareous coastal sediments is from rivers draining areas above the coastal plain, not local rivers (Giles and Pilkey, 1965). Swift (1975) has determined that the sediments were deposited offshore and were transformed during sea level rise, forming the origins of today's beaches and barrier islands. Sediments come from the erosion of coastal deposits in Virginia and North Carolina (Tanner, 1960).

Dunes

Dunes are elevated areas of unconsolidated sediment that are formed and maintained by wind transportation of sand. Dunes need four criteria to form and flourish: a sediment source; strong onshore winds; a gentle beach gradient; and, low humidity (which Florida does not

exhibit) and precipitation (Carter, 1988). The study areas experience winds strong enough to sustain the coastal dunes. This wind regime is conducive to dune stability. The beach gradient is gentle and suitable for both barrier island formation and dune formation. Dunes throughout Florida have formed as wind transports sand from the beach face inland. Vegetation traps sand by causing the wind speed to drop and deposit the wind blown or aeolian sand movement. In Florida sea oats are present along the coast. Sea oats are protected by law and cannot be removed (Florida Statutes, Chapter 370.041). The intent of this requirement is to recognize the importance of this hardy dune plant in establishing, and more importantly stabilizing Florida's dune system, which provides the first line of defense from storm and hurricane conditions. Webb et al. (1997) attribute dune removal to increased destruction of buildings along the panhandle of Florida during Hurricane Opal in 1995. Dune height and gradient is a function of sediment. Foster et al. (2000) attribute the gentle gradients on Anastasia Island to the fine quartz, compared to the relatively steep dunes in northern St. Johns County that are comprised of sand and shell particles (Mossa, 1993).

The broader barrier islands of the Florida coasts exhibit beach ridges. Beach ridges are a series of parallel ridges and swales. Ridges represent progradation seaward or parallel to the coast (Johnson and Barbour, 1990) and may be truncated or eroded by more recent events. There are four areas exhibiting beach ridges on the Florida Gulf coast (Schwartz and Bird, 1985) and beach ridges are present at Cape Canaveral and on Anastasia Island in St. Johns County (Stapor and May, 1982). Field (1974) estimates that Cape Canaveral beach ridge deposition took place 30,000 to 35,000 years BP.

Tide, Wave and Longshore Drift Characteristics

Tides in the study area are semidiurnal. The mean tidal range is 1.4 m (Foster et al., 2000) and the spring tidal range is 1.6 m. The average wave height at the Melbourne Beach wave gauge in Brevard County is 1.01 m, with an average wave period of 6.3 seconds. The prevailing wave direction is east-northeast (Olsen, 2003). In St. Johns County the mean significant wave height is

1.1 to 1.2 m. The prevailing wave and wind approach is from the northeast (Foster et al., 2000), although during the summer the wave direction is from the southeast with smaller waves.

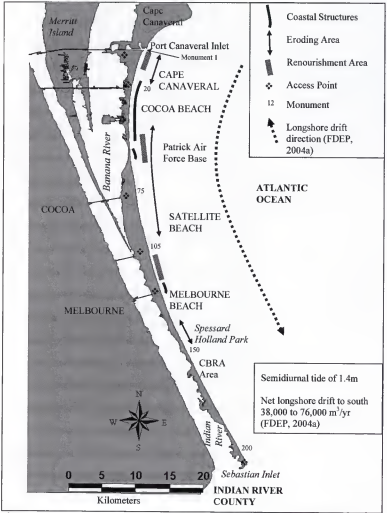

Figure 3-1. Coastal municipalities and geomorphic characteristics, Brevard County, Florida

The littoral drift on the east coast of Florida is predominantly north to south (Reesman, 1994). In Brevard County drift of approximately 38,000 to 76,000 m^3/yr is to the south (FDEP 2004a). However, Stapor and May (1983) have noted several littoral cells on the Northeast coast and describe Anastasia Island as an area of convergence and the area between Vilano Beach and Ponte Vedra as an area of divergence (Figure 3-2). Drift, predominantly during the summer, is to the north on Anastasia Island (Stapor and May, 1983). In St Johns County the prevailing drift direction is to the south and reported rates vary from 112,000 to 336,000 m^3/yr (Foster et al., 2000). Anecdotal evidence reports pulses of sediment along Ponte Vedra beach. This may be due to renourishment activities to the north (Foster et al., 2000). Fernandina beach was renourished in 1978. The Fort Clinch area in northern Nassau County was renourished in 1996. The dredging of St. Mary's inlet to accommodate the US Navy has resulted in the placement of material on Amelia Island (Reesman, 1994). On Anastasia Island the rate is lower at 152,000 to 228,000 m^3/yr to the south (FDEP 2004a).

Storms

The impact of storm activity is considered a long term and macroscale variable (Davis and Dolan, 1993). It is obvious that hurricane and storm activity impacts settlement decisions although the extent to which this impact influences settlement cannot be easily evaluated within a 30-year timeframe.

"The hurricane that hit in 1885 discouraged further settlement. The storm pushed the ocean waves over the barrier island (elevation 10 feet [3.2m]) flooding out the homesteaders. The beach near Canaveral Lighthouse was severely eroded prompting President Cleveland and the Congress to allot money for an effort to move the tower 1 mile [1.61 km] west" (Rabac, 1986, page vii)

The hurricane history of the two study areas is different in the long-term and over the 30-year study period. The record of hurricanes from 1872 to present shows that the east central

coast of Florida has experienced more direct storm activity than the northeast coast of Florida (Appendix A).

Table 3-1. Hurricane and tropical storm activity in the study areas

County/Area	Hurricane/ Tropical Storm Landfalls within 100 km since 1970	Hurricane/ Tropical Storm Historical Record	Exiting Hurricane Historical Record	Offshore Hurricane Historical Record
Brevard (east central Florida)	4/2	8/2	6	7
St. Johns (northeast Florida)	0/2	2/2	6	4

The distinction between burricanes and tropical storms was not made before 1890. The pattern of hurricane activity in Florida shows that storm intensities and numbers have varied. From 1931 to 1940 there were only six hurricanes. "1941-1950 [was] the most devastating decade in Florida's history since records were kept" (Williams & Duedall, 1997, pp. 18). There were 12 hurricanes that made landfall during that period compared to only three from 1951 to 1960 (U. S. Army Corps of Engineers, 1992). Brevard County has the distinction of extending further into the Atlantic than St. Johns County. The cuspate shape of the foreland renders it more vulnerable than the more embayed St. Johns County. Hurricane David was the first hurricane to strike the Brevard County area since the storm in 1928. The eye of the hurricane passed over the coast and moved back offshore, eventually making landfall in northeast. Hurricane Erin, which later impacted the panhandle of Florida, hit east central Florida in 1994 as a Category 1 hurricane. There have been two tropical storms that made landfall during the study period, in 1983 and 1994. This area also experiences indirect impacts of offshore hurricanes. For example, Hurricane Floyd in 1999 threatened the northeast Florida coast but remained offshore and eventually made landfall in North Carolina. The documented history back to 1872 shows that the region of northeast Florida experienced only two direct hurricane landfalls in 1880 and 1964. Hurricane Dora and the storm of 1880 are the only storms to have hit the northeast coast of Florida directly.

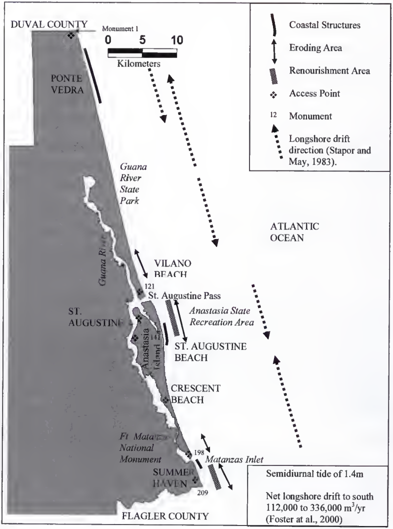

Figure 3-2. Coastal municipalities and geomorphic characteristics, St. Johns County, Florida

Hurricanes impacts in northeast Florida have been largely indirect with limited activity from storms traveling from the Gulf of Mexico over the peninsula and back into the Atlantic. Hurricane conditions were experienced in 1964, when hurricane Donna passed over north central Florida. This hurricane was exiting Florida and moving offshore having passed over Florida's north central peninsular area. In addition to direct hits and winter storms, Northeast Florida is prone to indirect storm impacts. The recognized recurve pattern of storm paths up the southeastern United States impacts the area. In northeast Florida indirect hurricane conditions have caused flooding of infrastructure, storm surge and dune erosion and wind damage (Reesman, 1994). Storms during the 1990's have caused local erosion along the northeast coast. Hurricane Floyd in 1999 threatened the northeast Florida coast but remained offshore and eventually made landfall in North Carolina. The northeast Florida study area has not experienced any direct hurricane landfall during the 27-year research.

The most recent 2004 storm history is after to the data used in this research. However, it is important to note that three storms impacted the study areas. Brevard County experienced hurricane conditions from Hurricanes Frances and Jeanne. Both these storms also produced tropical storm conditions in St. Johns County. The impacts on the St. Johns County renourishment projects are discussed in the results section. Hurricane Charley also exited south of St. Johns County, in the vicinity of Daytona Beach.

Winter Storms

Winter storms or Nor'easters are extratropical storms that impact the coast from October to April. Although they may not have the extreme wind speeds associated with hurricanes they affect wider swaths of the coast because they are larger and may stall over coastal areas. These storms can be over 1,000 km wide and cause surges of over 4.5 m. Prolonged wave activity enhances the destructive capacity of a winter storm. Nor'easters derive their names from the prevailing wind direction. These storms rotate counterclockwise and travel north along the east coast of the United States (Davis and Dolan, 1993). The low-pressure core is accentuated by high

jet stream winds. The position of the jet stream each season affects the number and type of winter storms (Davis and Dolan, 1993). The Department of Environmental Protection surveying patterns show that winter storms have impacted the study areas. DEP performs post-storm condition surveys and from these records there have been storms that impacted the geomorphology sufficiently that resurveying was performed, usually in small segments of a county. In Brevard County winter post-storm resurveying was carried out in 1973, 1981, and 1985. The DEP records indicate winter storm activity in 1981 and 1984 in northeast Florida. Reesman (1994) notes that winter storms impacted the northeast Florida region in 1932, 1947, 1962 and 1973. The U. S. Army Corps on Engineers (1992) lists 28 storms that impacted St. Johns County between 1977 and 1993. It should be noted that the resurveying of areas is also a function of the state budget. State funding inconsistencies necessitate caution in concluding that geomorphic impacts occurred only during these events.

Development History

The land uses in Brevard County have evolved from citrus production to high-density residential and commercial uses. Figures 3-3 and 3-4 show the development patterns at the same position in Brevard County. In 1950 Cocoa Beach was approximately half built out and in 1972 was 75 percent built out (Bodge, 1992). The 1972 aerial photography shows there was no development adjacent to the Port Canaveral Inlet jetty. In the City of Cape Canaveral roads are perpendicular to the shore and residential and multifamily development was present. In 1985, 95 percent of the Cocoa Beach was built out (Bodge, 1992). Between Cape Canaveral and the residential area in south Cocoa Beach high-rise residential, commercial and large impervious parking areas were present. Residential lot sizes in Cocoa Beach are small and development is dense. There were large structures and areas of impervious surface, such as the Pam Am world headquarters, which had been redeveloped into high-density condominia by 1997. Patrick Air Force Base was renovated between 1986 and 1997 and the base housing was redeveloped at higher densities. South of the Base infill and development on vacant lots has occurred. Brevard

County south of monument 118 has similar characteristics to northern St. Johns County with a single shore parallel access and large low-density single-family development. The Coastal Barrier Resources Act covers the section between monuments 157 to 164, so that development is this area cannot receive federal assistance for flood insurance or roadway construction.

Development in the barrier islands of northeast Florida has occurred predominantly since Hurricane Dora in 1964 (Reesman, 1994). The coast of St. Johns County is 66.5 km from Duval to Flagler County to the south (FDEP, 2004b). Figure 3-2 shows the locations of the inlet, coastal municipalities and parks referred to in this research. In 1972 St. Johns County was not intensely developed. There are several sample 9-hectare plots with no development at all. The development that existed was sparse single family, mobile home and small commercial. To the north at Ponte Vedra at monument 2 the Ponte Vedra Golf Club was constructed. However, it is clear for the lack of residential development surrounding that area that the influences of Jacksonville as a metropolitan area did not extend to northern St. Johns County. Along Anastasia Island in 1972 there are large undeveloped areas. Highway AIA is routed away from the coast leaving large areas with potential for development. In 1972 there were 3 large trailer or RV developments. These consisted of a concrete pads and utility connections. Large-scale condominia, hotels and motels were not present except at St. Augustine Beach. South of Matanzas Inlet there was development immediately adjacent to the inlet, and none on the spit between the Matanzas River and the Atlantic.

In 1986 single-family development had expanded. Large homes had been constructed in the Ponte Vedra Area and Vilano Beach was beginning to develop with smaller single-family homes. The Ponte Vedra commercial area had expanded. The construction of homes further south on AIA was occurring. Just north of St. Augustine Pass, in the area protected by rocks, a single-family neighborhood had developed by 1986.

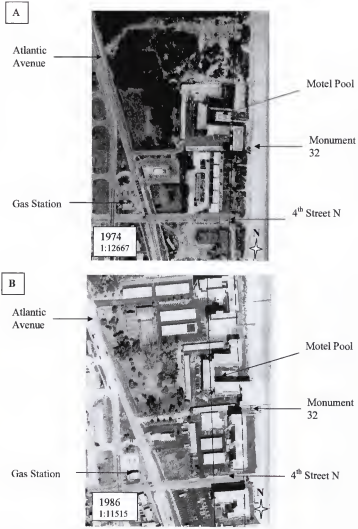

Figure 3-3. Urbanization at monument 32, Brevard County. A) 1974. B) 1986.

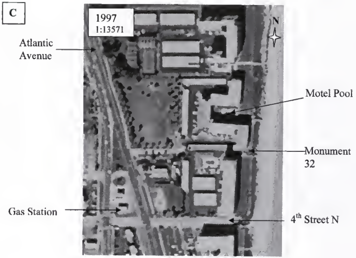

Figure 3-4. Urbanization at monument 32, Brevard County, 1997

On Anastasia Island large condominia and hotels were beginning to be constructed on previously vacant tracts. Single-family homes were also removed for these projects and two of the three travel trailer parks were replaced with multi-story residential structures and associated parking and amenities, such as pools and tennis courts. South of Matanzas Inlet homes were built on the spit. By 1999 northern St. Johns County was developed with single-family homes, and the influence of the Jacksonville metropolitan area is evident. Homes in this area are large and smaller homes have been enlarged or replaced.

Inlets

Brevard County has two inlets, Port Canaveral to the north of the study area and Sebastian Inlet that marks the boundary with Indian River County (Figure 3-1). Sebastian Inlet is man-made and has been maintained since 1948 by dredging and the installation of jetties (Wang and Lin, 1992). The Port Canaveral Inlet was stabilized in the 1940's. It has been theorized that the

stabilization of the inlet impacted stabilization of the foreshore in Coca Beach. However it is unlikely that any influence downdrift extends beyond 0.62 km (Bodge, 1992). Port Canaveral Inlet is dredged to a depth of 13 m, although during Hurricane Frances in 2004 shoaling decreased the depth to 8 m (FDEP, 2004a). Dredge material is too fine for beach placement and is disposed offshore (FDEP, 2000a). Subsequent to this study period the Department of Environmental Protection adopted an inlet management plan to bypass beach-compatible sand to nearshore-disposal areas adjacent to monuments 1 to 14 (FDEP, 2000a)

Figure 3-2 shows the two inlets in St. Johns County, St. Augustine Pass south of Vilano Beach and north of Anastasia State Recreation Area, and Matanzas Inlet between Anastasia Island and Summer Haven (FDEP, 2000b). St. Augustine Pass was dredged initially in 1940. The inlet has jetties on the north built in 1941, and south, built in 1958 (McBride, 1987) and is maintained by U. S. Army Corps of Engineers (Foster et al., 2000). At Matanzas Inlet a revetment and bridge abutment, initially constructed in 1925, reinforces the south shore. This inlet is not dredged. South of Matanzas Inlet the coast is protected by structures and designated an area of critical erosion (Clark, 1999).

Coastal Structures

Structures will impede the transfer of sediment from the foreshore to the dune system (Carter 1988, Gares, 1987, Nordstrum, 1994). Coastal armoring in the form of parallel structures has been shown to increase scour and hasten the removal of sand in the foreshore (Beatley, et al., 1994, Carter 1988, Pilkey and Dixon, 1996, Pilkey, and Clayton, 1989). Therefore, the presence of structures may impact the beach width, by steepening the beach. Coastal structures are present in St. Johns and Brevard Counties (Figure 3-1 and 3-2). Brevard County has an extensive length of shoreline in Cocoa Beach that has a seawall. In 1950 there was about 300m of bulkhead at Cocoa Beach (Bodge, 1992). In 1972 over 20 percent of the coast had bulkheads compared to 7 percent in 1950. By 1985, 95 percent of the Cocoa Beach area was built out and 48 percent had bulkheads. Brevard County has many formal and informal (individual resident initiated)

shoreline protection structures. St. Johns County contains two areas with shore-parallel structures in Ponte Vedra and St. Augustine Beach (St. Johns County, 2002). At St. Augustine Beach, piles of rock stabilize the point at which Highway A1A turns west (monument 141). Previously Highway A1A continued further north on Anastasia Island until it was threatened by erosion during hurricane Dora. There are no extensive bulkheads or seawalls from Ponte Vedra to Vilano Beach, although individual homeowners have made small-scale private attempts (St. Johns County, 2002).

Renourishment of the Shoreface

Brevard County has had several renourishment projects during the study period, which are shown in the Table 3-2. Brevard County has 115.2 km of coastline (including the Cape Canaveral National Seashore, that is not part of this research) and 16.7 km has been renourished (Esteves, 1997). There are also instances where individual homeowners have attempted informal and unpermitted shoreline protection methods. Localized small-scale protection, sand fencing or netting, and planting of dune vegetation are not considered coastal structures and not included in this variable.

Table 3-2. Renourishment projects in Brevard County during 1972 to 1997 study period

Monument/ Location	Alongshore Distance (km)	Date	Volume (m^3)
(Not in research area)	Unknown	1972	152,900
1 to 33	Approx 3	1974-75	2,075,889
119-134	Approx 4.5	1980-81	412,938
50-76	Approx 6	1985	550,512
City of Cocoa Beach	Unknown	1986	30,580
City of Cape Canaveral/Cocoa Beach	Unknown	1992	99,398
City of Cape Canaveral/Cocoa Beach	Unknown	1993	152,920
City of Cape Canaveral/Cocoa Beach	Unknown	1995	567,333

Source: Brevard County Comprehensive Plan, 1988, Sudar et al., 1995. Esteves, 1997, Pilkey and Clayton, 1997.

There has been no large-scale renourishment activity in the portion of St. Johns County examined during the study period (Pilkey and Clayton, 1997). However, of the 66.1 km of

coastline, 2.8 km have been renourished (Esteves, 1997) in Anastasia State Recreation Area. The park was renourished in 1963 when 38,230 m^3 of sediment was added (Dean and Donohue, 1998). In 2000 renourishment began at St Augustine Beach (monuments 140 to 147) and in 2001 at Summer Haven (monuments 200 to 207). Renourishment using sediment dredged from St. Augustine Inlet was carried out in Anastasia State Park in 2002 (Dean and Donohue, 1998). While Anastasia State Park is not included in the study area because it is excluded from development as a State Park, sediment from renourishment projects enters the coastal system on Anastasia Island, downdrift of the park.

Table 3-3. Recent renourishment projects, Brevard County.

Monument Location	Alongshore Distance (km)	Date	Volume (m^3)
3-54.5	15.13	Oct. 2000-April 2001	2,435,720
53-60	4.99	Dec. 2000-April 2001	454,670
122.5-139	4.86	Feb-April 2002	899,000
118.3-123.5	1.51	March-April 2003	175,840

Source: Olsen (2003)

Table 3-4. Recent renourishment projects, St. Johns County.

Monument Location	Distance (km)	Date	Volume (m^3)*
140-147 St Augustine Beach	Unknown	2000	Unknown
132-152	6.12	Sept. 2001-Jan 2003	848,930
Summer Haven	Unknown	2001	Unknown

*Excludes Anastasia State Recreation Area.

Source: FDEP (2004a), Dean and Donohue (1998).

CHAPTER 4
METHODOLOGY

This research is divided into two areas of inquiry; the influence of the actual geomorphology and the impact of geomorphic variability, on planned and actual coastal development in two regions of Florida over a 27-year period. The actual geomorphology affords temporal analyses of impacts. Geomorphic variability enables spatial distributions and patterns to be investigated along the shore. The two regions investigated have experienced different storm and hurricane influences (Appendix A) and are governed by separate policy making entities.

The availability of geomorphology data obtained from the State of Florida, Department of Environmental Protection (FDEP) is shown in Table 4-1. From these data the variables shown in Table 4-2 and Appendix B are derived. The maximum dune height (DH), distance of maximum dune height from National Geodetic Vertical Datum (NGVD) (DHBW), beach width index (BW), the distance from the monument to the maximum dune height (MDH), are shown in Figure 4-1. Long-term shoreline change (LT), shoreline orientation (OR) the presence of reinforcement structures (SW), the erosion status (ER) and past renourishment activities (RN) are also included in the analyses as independent variables. These variables characterize the time-specific conditions.

Development variables include land use from local comprehensive plans (FLU), the future land use plan densities (FLUD), the number of residential dwelling units (UN) (of 8 or less dwelling units per structure), units per hectare (UH), percentage impervious area (PIM), and hectares of commercial land use (C). The distance to the nearest access point to the coastal area by causeway or major highway (ACC) and distances incorporating a direction component (DACC), the position of the shore parallel highway (ROAD) and the geographic location (POS) are also included in the analyses as dependent variables.

All development variables use primary data sources and are derived for this research from maps and photography. Each of the geomorphic variables are collected at monuments located approximately 300m apart along the entire coast of Florida, excluding the Big Bend area and Florida Keys. Development, or human variables are collected in sample areas adjacent to the monument. Sample areas were selected to maximize analyses coverage. Sample areas were designed to extend an equal distance wither side of the monument by 150m. The 300m dimension alongshore and inland results in a 9-ha square sample area. The sample area is oriented parallel to the shore and perpendicular to the meridian (Appendix D). The seaward extent of the 9-ha sample area is defined by the extent of the digital land use coverage from the DOQQ's.

The influence of beach width, maximum dune height, distance to maximum dune height, distance from the monument to the maximum dune height and long term shoreline change on the actual and future land use, number of dwelling units, impervious area and development potential is evaluated at each time period.

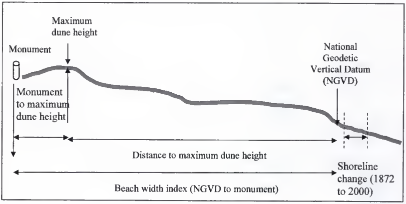

Figure 4-1. Beach profile and geomorphic variables

Actual Geomorphology Variables

The coastline of Florida has been surveyed by the Division of Beaches and Shores, State Department of Environmental Protection (FDEP) since the early 1970s (Clark, 1999). Monuments are situated along the coastal counties of Florida approximately every 300 m and are typically set within the dunes. The FDEP collects data for a variety of reasons, such as to assess local conditions, evaluate the coastal construction control line and for special purposes. Complete data sets are available in each decade of the research (Table 4.1). Partial data sets for counties are collected for post-storm evaluation, and pre- and post-construction. Data from contracted surveys are also included on the FDEP website, but are not used in this research. An example of the format of the raw data is shown in Appendix C.

Beach Width Index (BW)

Beach width variations reflect areas along a barrier island that are more dynamic, those that erode and recover more than adjacent areas. This variable has been used by Davidson-Arnott (1988) and Gares (1988). Beach width is an important variable in the selection of locations for development. During Hurricane Hugo beaches of over 30 m wide afforded greater protection to structures, and 84 percent of coastal structures that were destroyed had a beach width of 15 m or less (Bush et al., 1999). The FDEP beach profile data are modified to represent beach width (BW). The distance from the survey monument to the water (using the National Geodetic Vertical Datum, NGVD) is calculated. NGVD is defined as the National Geodetic Vertical Datum, as established by the National Ocean Survey in Chapter 62 of the Florida Administrative Code[1]. NGVD provides a suitable zero point for this research because NGVD is used as a

[1] In the United States 75,159 km of leveling was standardized in 1929. A fixed elevation was assigned to 26 points on a network that defined elevations in the United States and Canada as the mean sea level datum of 1929. This was commonly referred to as "mean sea level" and was confused with "mean water level" until 1979. It was renamed the National Geodetic Vertical Datum of 1929.

baseline for the FDEP surveys and is consistent throughout the two study areas and the entire study period.

Table 4-1. Geomorphic data availability by study area

Study Area	Data Availability
Brevard County	1972, 1983~, 1986, 1993~, 1997
St. Johns County	1972, 1984~, 1986, 1993~, 1999

~ Data are incomplete or only available every 3 monuments

Table 4-2. Independent (geomorphic) variable details

Independent Variables	Name
Beach Width Index	BW
Maximum Dune Height	DH
Monument to Maximum Dune Height	MDH
Beach Width to Maximum Height	DHBW
Long-term Shoreline Change	LT
Geographic Location	POS
Orientation	OR
Distance to Access Point	ACC
Distance and Direction to Access Point	DACC
Presence of Structures	SW
Renourishment	RN
Dune Renourishment (Brevard County only)	RND
Temporal Scale	**Name**
Actual	
1972	t1
1986	t2
1999 (1997 Brevard)	t3
Dynamic	
Change from 1972 to 1986	t2-1
Change from 1986 to 1999(1997 Brevard)	t3-2
Change from 1972 to 1986(1997 Brevard)	t3-1
Total Change (Absolute Value)	tot
Change Factor (Ratio Net to Total)	f

Appendix A contains source and measurement data for each variable.

The monument is a fixed position on the profile. The monument location varies in certain instances. When a monument is lost it is replaced by the State of Florida. If the monument was lost as a result of storm activity or erosion the replacement may be in a new location. The beach width index from the monument to the NGVD is a measure of relative beach width, and is measured in meters. The beach width index variable illustrates the changes in width over time.

Table 4-3. Profile measurement metadata, monuments 1 to 200, Brevard County

Brevard County-1972		Brevard County-1986 Cont.	
Date	Monument Number Range	Date	Monument Number Range
9/13/72	1-40	12/19/85	68-86
9/20/72	41-79	1/7/86	123-126
9/21/72	80-95	1/8/86	121, 122
9/26/72	96-107	1/9/86	97-120
10/3/72	108-120	2/4/86	136-155
10/26/72	121 -128	2/5/86	127-135
11/8/72	129-134, 151-162	2/6/86	156-172
11/7/72	135-150	2/19/86	174-186, 201, 204, 205
11/9/72	163-195	2/20/86	187-193, 194-200
11/16/72	196-211	2/21/86	173, 202, 203
11/27/72	212-219	3/5/86	209-218
		3/6/86	193, 206-208
		3/7/86	219

Brevard County-1986		Brevard County-1997	
Date	Monument Number Range	Date	Monument Number Range
8/27/85	1-13	10/97	1-219
8/28/85	14-23		
8/29/85	24-46		
12/4/85	52-67		
12/5/85	47-51		
12/18/85	87-96		

Maximum Dune Height (DH) and Distance to Maximum Height (DHBW)

Dune Height (DH) and the Distance to Maximum Dune Height (DHBW) are important site-specific variables that are strong determinants of susceptibility to inundation (Bush et al., 1999; Fisher, 1984; Gares, 1988). Maximum dune height is defined as the highest point on the profile that is recorded seaward of the monument. By considering the point seaward of the monument, variations due to the extent of the profile inland are controlled. The Distance to the Maximum Height variable is the distance from NGVD to the maximum height. This variable gives an indication of the position of the highest point on the profile to the shoreline, rather than the fixed point of the monument. The importance of the interaction between sediment on the foreshore and supply to the dunes reflected by the Distance to the Maximum Dune Height has been discussed by Davidson-Arnott (1988). The distance to maximum height variable gives an

indication how the dune field characteristics have altered over time and reflects the importance of the interaction of the foreshore and dune systems (Psuty, 1988).

Monument to Maximum Dune Height (MDH)

The Distance to Maximum Height is a measure from one geomorphic characteristic, Maximum Dune Height to NGVD. The Monument to Maximum Height measures a static point on the profile, the monument, to a dynamic geomorphic feature, the Maximum Dune Height. Psuty and others (1988) found that the position of the dune is less dynamic than other geomorphic features. They also showed that the inland movement of dunes does necessarily exhibit a direct relationship with the dynamics of the beach, so that landward migration of the dune may not necessarily indicate that the foreshore is eroding. This variable is particularly important where the Beach Width Index and NGVD to Maximum Dune height are impacted by structures. In locations where shore-parallel structures are present, geomorphic changes in the profile seaward of the structure will be impacted. On such profiles the Monument to Maximum Dune Height may represent the part of the profile where sediment movement is occurring.

Long Term Shoreline Change (LT)

Historical shoreline change has been calculated at each monument by the State of Florida and is intended to be used to "assist in growth management and regulatory programs" (Foster and Savage, 1989, pp. 4434). Long-term shoreline change is influenced by longshore sediment transport, sand supply, wave climate, geographic features such as estuaries and man-made structures and nearshore reefs. The FDEP, using the end point, least squares, and rate averaging methods, calculates long-term shoreline change between 1872 and 2000 (Foster et al., 1999, Foster et al., 2000). These data were available for St. Johns County (Figure 4-2). Long-term change rates for Brevard County were calculated using rate averaging and end point rates (Figure 4-4).

The end point rate is the difference between the first record and the last record divided by the entire time period. The end point rates are calculated similarly to net change variable for the profile data. However, the data are taken from historical maps, shore normal profile data, and digitized historical shorelines from the U. S. Coastal and Geodetic Survey, the National Ocean Survey (NOS) and the U. S. Geologic Survey. The least squares method models the slope of the best-fit line when shoreline width and time are plotted. The rate averaging method is the average long-term rate of change using a combination of rates over the time periods. The magnitude of the end point methodology determines which records are used. If the end point methodology shows a small amount of change, it should take a longer time between observations to detect significant shoreline changes. The FDEP also conducts rate comparison, sensitivity and digitizing variability tests to determine the points to be included. The time period for each data point collected is calculated. Data obtained from maps verses surveyed profiles will have different degrees of accuracy and different minimum time span requirement. Rate combinations over a time period shorter than the data type minimum are excluded as not reflecting long-term trends. In this way, short time segments do not influence the calculated rates unduly. All three methods are compared to demonstrate specific sensitivity to any of the methods.

Each methodology has potential for errors. Each of the records has a level of accuracy determined by the source information. The end point data gives a net effect that is useful in areas where there have been continuous changes, such as the impact of beach renourishment (Houston, 1995) that would influence the results of the other methodologies. Using this methodology data irregularities are dampened. The least squares fit method is sensitive to clusters of records (Figure 4-4). In the case of shoreline information the data are sparse in the earlier time periods and more comprehensive in the recent past. The least squares method does not afford a weighting system to increase the emphasis on more accurate data.

Table 4-4. Profile measurement metadata, monuments 1 to 209, St. Johns County

St. Johns County-1972	
Date	Monument Number Range
8/1/72	182-209
8/2/72	155-181
8/3/72	141-154
8/15/72	123-140
8/28/72	103-122
8/30/72	63-102
8/31/72	41-62
9/5/72	33-40
9/6/72	1-32

St. Johns County-1986	
Date	Monument Number Range
7/15/86	1-7
7/16/86	8-16
7/17/86	18-26
7/18/86	17
7/28/86	27-30
7/30/86	31-32, 36
7/31/86	37-40, 44, 45
8/1/86	33-35, 41-43, 46-50
8/12/86	51, 52, 91-98
8/13/86	54-56
8/14/86	57-60
8/15/86	61, 62
8/19/86	63, 99-106
8/20/86	64-66
8/26/86	67-76
8/27/86	77-90
9/9/86	107-109, 123-125
9/1086	110-117, 126-135
9/11/86	118-122, 136-143
9/12/86	200-209
9/20/86	143A
9/23/86	144-153
9/24/86	154-166
9/25/86	167-171
10/10/86	172-178
10/23/86	179-188
11/4/86	189-199

St. Johns County-1999	
Date	Monument Number Range
2/25/99	1-3, 7-13
2/26/99	4-6, 14-21
3/16/99	22-36, 58-68
3/17/99	37-57, 69-80
3/18/99	81-93, 109-121
3/19/99	94-121
3/30/99	122-123
3/31/99	124-125
4/1/99	126-134
4/2/99	135-137
4/13/99	138-141, 147, 151-154
4/14/99	142-146, 148 –150, 155-158
4/15/99	159-166
4/16/99	167-170
4/27/99	171-185
4/28/99	186-191
4/28/99	192-196, 197A, 198
4/30/99	197, 199-207

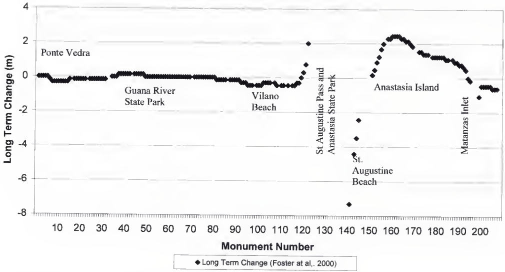

Figure 4-2. Long-term shoreline change, St. Johns County, 1872 to 2000

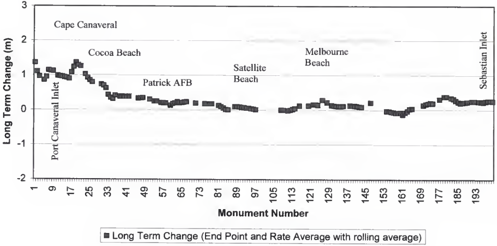

Figure 4-3. Long-term shoreline change, Brevard County, with data ranges from 1877 to 2001

53

The rate calculation method (figure 4-5), which averages all the long-term rates of change, reduces the influence of random profile variability, seasonal influences and measurement error inherent in the different data types. The rate averaging calculation is considered the most accurate of the methods (Foster and Savage, 1989) although the comparative methodology using all three produces long-term shoreline change rates less influenced by extreme values derived from a specific methodology.

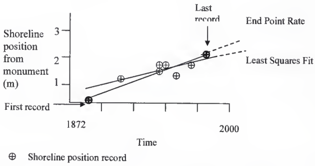

Figure 4-4. Calculation of long-term shoreline change, end point and least square fit methods

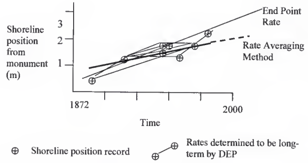

Figure 4-5. Calculation of long-term shoreline change, rate-averaging method

Foster and Savage (1989) suggest that the averaging of shoreline change rates between adjacent profiles, or longshore averaging, minimizes errors. The length of the segment of coastline included in the longshore average is important. A segment that is too long will oversimplify and obscure local conditions. A segment that is too short may be impacted by an individual profile that is not reflective of the segment. The number of points selected is also determined by local conditions, such as the extent of coastal structures and the presence of inlets. Projections of shoreline change are made in light of the current conditions. It is reasonable to assume that a single storm event in the future could render the estimates invalid. Similarly areas experiencing substantial changes may reach equilibrium and the rate of change will slow. In locations where coastal structures are present, rate of change may temporarily cease when the structure is reached (Wright, 1991).

This methodology does not accommodate the influence of sea level rise, land subsidence or emergence. Foster (1992) does not consider these to be significant factors in Florida for the calculation of long-term (greater than 100 year) shoreline change. He concludes that the impacts of sea level rise are obscured by the variability in tides, storms and longshore sediment transportation. The impact of shoreline protection structures and beach renourishment are also random (Foster, 1992). Data frequencies used in this research area also insufficient to illustrate such short-term impacts as seasonal changes and the influences of wave and tidal climates. The timeframe considered in this research is insufficient for sea level impacts to be quantified and infrequent enough for short-term influences with records only each decade. However, while the timeframe is unsuitable for these scales it is well suited for the analysis of development and plans for development. A longer spectrum would take the research beyond the development horizon and required future land use planning documentation.

Long-term change evaluation Brevard County has not been conducted to by the FDEP. However, long-term shoreline change rates are derived using the "Historical Shoreline Position

Database" (http://hightide.bcs.tlh.fl.us/counties/HSSD/readme/read.me1) and published long term change rates (Olsen and Buckingham, 1989) and are shown in Appendix F. The Shoreline Position Database directory contains 150 years of shoreline data for each county. For Brevard County the earliest records are shown below. Where a span of years was indicated the latest record was used. The end point method noted above was used to determine the long-term change rates for Brevard County (Figure 4-3) and the extent of the record eliminates the extremes of variability from the more recent data (McBride and Byrnes, 1997; Esteves, 1997).

The shoreline position from the monument to the mean high water (MHW) level is indicated, which is a similar measure to the beach width variable in this research. The MHW position has been determined by FDEP from USGS topographic maps, photography and FDEP profile surveys. Inaccuracies noted include high wave activity (specifically in the 1980 data) and sun glare that would influence aerial photo interpretation. Aerial photography is the basis of maps since 1920. Before 1920 plane table surveying was used (Foster, 1996). The data from 1970 is not recommended for use in Brevard County without aerial verification. Not withstanding the limitations, the extent of the long-term data are useful and the only known source of long-term data (Galgano and Leatherman, 1991).

Olsen and Buckingham (1989) prepared rate averages from the earliest Brevard County record to 1986. The rate average and end point rates for all points in Brevard County vary from each other by 3 cm. The average value of the derived end point rate and rate average value was determined. This value for each monument was averaged with the rates immediately to the north and south, if available, as recommended by Foster and others (2000).

Coastal Structures (SW) and Renourishment Projects (RN, RND)

Each monument location is reviewed for the presences of shoreline protection structures (St. Johns County, 2002; Bodge and Savage, 1989). Structures will impede the transfer of sediment from the foreshore to the dune system (Carter 1988; Gares, 1987; Nordstrom, 1994) and prevent the Dune Height variable from reflecting geomorphic processes. The presence of

structures may impact the Beach Width Index, by steepening the beach and reducing the distance to NGVD. This variable is recorded categorically as structures present or absent only.

Table 4-5. Brevard County shoreline position records

Monument Range	Earliest Record	Most Recent record
1–77	1877	2001
82-84, 94	1877	1999
78-81, 85-93, 95-108	1877	1997
116-120, 147, 157, 164, 169	1878	1999
108-114, 122-143, 148-154, 156, 162-163, 165	1878	1997
159	1878	1993
155, 158, 160-161, 170	1878	1986
182, 186, 198	1879	1999
171, 172, 174-180, 183-185, 188-197, 199, 200	1879	1997

Source: http://hightide.bcs.tlh.fl.us/counties/HSSD/readme/read.me1

Renourishment of the coast during the study period will affect geomorphic variables, but is initiated and made necessary by human presence on the coast. This variable is recorded categorically as renourished or not (RN) and areas of renourishment are outlined in Chapter 3. Brevard County has practiced dune renourishment (Olsen, 1989; Brevard County Comprehensive Plan, 1988; Foster et al., 2000), which is recorded as a separate variable, RND.

Geographic Location (POS) and Orientation (OR)

The geographic location variable is a measure of the position of the center of the 9-ha sample area from of the monument, along the coast. A smaller number indicates a location further north in the respective county. This variable in conjunction with the analyses of data by geomorphic unit provides spatial context the statistical analyses. In Brevard County the

dependent variable data are not available for Patrick Air Force base. Brevard County data were considered as two separate areas; Cape Canaveral to the north point of PAFB, (monuments 1 to 71); and, south of PAFB to Sebastian Inlet (monuments 75 to 200). In St. Johns County dependent and independent variables for the entire county are considered together and in separate arrays representing the area north of St. Augustine pass (monuments 1 to 122) and Anastasia Island (monuments 141 to 195). Using ArcGIS the orientation (OR) of the shoreline was digitally obtained. Each 9-ha sample area was centered on the monument, using the meridian described earlier. The axis of the meridian was oriented at right angles to the shoreline, determined from the extent of the GIS land use coverage. Using the angle command the orientation of the leading edge of the 9-ha sample was determined.

Distance (ACC), Direction (DACC) and Location (ROAD) of Access

The distance of the 9-ha sample area to the nearest access point to the mainland was considered a potential determinant of development sequencing or geographic weighting, in that sample areas closer to bridges or access point are likely to have developed before sample areas further from access. The exact location of the monument was used to derive the distance to access. In each county the location of causeways and access points was determined using GIS. The DACC variable adds a direction component to the measurement of distance to the nearest access point. A positive value represents that the nearest access is to the south and negative, to the north of the monument.

In Brevard County there are five causeways. State Road 528 reaches the coast at Bennet Causeway in Cape Canaveral, adjacent to monument 1. State Road 520 accesses the barrier island between monuments 20 and 21. Pineda Causeway carries State Road 404 and reaches the coast between monument 75 and 76. State Road 518 crosses the Indian River on Eau Gallie Causeway at monument 105. The southernmost access to the barrier island in Brevard County is US 192 at monument 123. In St. Johns County, monument 1 is considered the closest monument to access to the north. At monument 35, Mikler Avenue also provides direct access to the west.

The bridge north of St. Augustine Pass provides access at monument 121 on US AIA. St. Augustine Beach is provided access by the Bridge of Lions (State Road 214) and the State Road 312 bridge that reaches the coast at monument 140. State Road 206 provides access to Anastasia Island at Crescent Beach at monument 174.

ROAD, or location of access in the 9-ha sample areas, was recorded using the DOQQ's in the T3 period. The location of the shoreline parallel access is a measure of the potential for development locations. This variable was weighted from a value of 1 to 4 using the location of the shore-parallel access, shown in Figure 4-6. Location of the road in the seaward third, or first 100 m of the 9-ha sample area was designated a 3. The exception to the diagram below was the presence of more than one shore parallel highway, which was designated as a 4.

Dynamic Geomorphology Variables

The dynamic geomorphology variables are a measure of the amount of change each variable has experienced over the study period. Beach width is used to illustrate the concept the net (BW_{t3-1}) and total change (BW_{tot}) variables (Figure 4-7). The calculated beach width for each profile, for each time period is used to determine the net and total beach width changes. The net change is calculated by subtracting first recorded width (BW_{t1}) from the most recent beach width (BW_{t3}). A positive value over the study period indicates net accretion, or increase in the distance to NGVD from the monument. The net change provides a measure that is an important indicator of the 27-year pattern. This is the same method used to calculate the end point rate, a component in the Long Term Shoreline change variable. In areas where continuous changes have occurred, the net change shows the net effects regardless of the series of events, storm impacts or variation in the times of year the data was collected. Using this variable, data anomalies are smoothed. Beach width variations reflect areas along a barrier island that are more dynamic, those that erode and recover more than adjacent areas. The total beach width change variable represents the total changes in beach width for the entire time period.

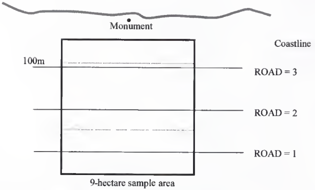

Figure 4-6. Determination of highway location (ROAD) variable

Figure 4-7 shows the calculation of total beach width change. The net change from 1972 to 1997 (BW_{t3-1}) is 20 m for both examples, and is the total change for **a.** However, the total change (BW_{tot}) is 40 m for profile **b**. Total change is the cumulative change from the initial data year to the final year. The total beach width change value is always positive (or zero) because the value is the sum of the change in the shoreline position of the edge of the beach each year. Profiles that experience both erosion and accretion will have a much larger total beach width change than net beach width change. The net variation and total variation in maximum dune height is also calculated using the same methodology. Variations in the distance from the point of maximum height to NGVD are also used as an indicator of a geomorphically dynamic area.

A factor for each of the geomorphic variables is developed using the Total and Net changes. The factor is a ratio of the Net change to Total change. The Total change is an absolute value, whereas the Net change value can be positive or negative. The Factor maximum value is 1.0 and minimum is –1.0. A Beach Width Factor (BW_f) of 1.0 represents a beach width that has accreted from the first measurement to the last (Figure 4-6a). A negative Beach Width Factor indicates that the shoreline has retreated during the time period. In both Figure 4-8 a) and b) the Net Beach Width (from the 1972 to 1997) is 20 m. The Total change is 20 m for a) and 40 for b).

The Beach Width Factor for situation a) is 1.0 indicating continuing accretion. In situation b) the Beach Width Factor is 0.5. The positive value indicates net but not continual, accretion. A negative Beach Width Factor indicates the Net change has been negative. A Beach Width Factor of –1.0 indicates an eroding shoreline.

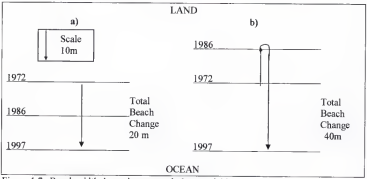

Figure 4-7. Beach width dynamic geomorphology variable

Compilation of Data

Data from the FDEP website are used in raw form to avoid rounding, aggregation and other errors. These data require considerable manipulation to render them suitable for analysis. Data from each county must be reviewed for completeness of record. Data sets that contained information only at 1,000-meter intervals or for a localized range of monument for each county were not used. Data were imported and converted so that the geomorphic variables could be extracted. Each monument placement was reviewed and adjusted in instances where the monument was relocated. Using the methodology proposed by Rahn (2001) any monument that had been moved in excess of 3m north or south of the original position was excluded. The 3m dimension assumes that the profile continues to reflect the local topography. Monuments using the same azimuth that were relocated landward were suitable for use, but only the portion of the profile present in the earlier positioning of the monument was used.

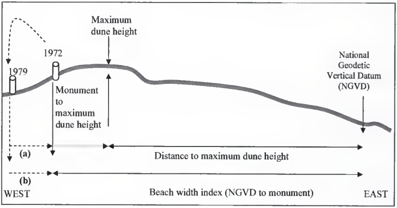

Figure 4-9. Profile revision diagram, monument moved landward (to west)

In the case where the revised monument position is west of the original position the profile, data recorded after the repositioning are adjusted (Figure 4-9). Relocation landward results from monument destruction from storms, coastal erosion, profile changes and construction at the original monument location (Foster 2002, personal communication). Profile data recorded are amended to reduce the monument to maximum dune height **(a)**, and the beach width index (NGVD to monument) **(b)**, for consistency amongst all the data sets. The standard of 3m in north-south variation is assumed not to necessitate amendments in dune height variables (Rahn, 2001). In cases where the maximum dune height occurs at the landward of the original monument position, the maximum dune height recorded at or seaward of the original position is used.

In the case where the revised monument position is seaward or east of the original position the profile data recorded before the repositioning are adjusted (Figure 4-10). Relocation landward occurs due to construction at the position of the monument and road realignments (Foster 2002, personal communication). Profile data recorded before the repositioning of the monument are amended to reduce the monument to maximum dune height **(a)** and the beach

width index (NGVD to monument) (b) for consistency amongst all the data sets. The standard of 3 m in north south variation is assumed not to necessitate amendments in dune height variables (Rahn, 2001). However, in cases where the maximum dune height occurs at the monument, the maximum dune height recorded at or seaward of the new position is used and the maximum height to NGVD is amended.

Table 4-6. Sample data changes for landward (west) relocation of monument

1972	1972 data are unchanged
1979-Monument relocated landward (west) 10 m in 1979	
1986	Amend: (a) Monument to maximum dune height reduced 10 m Beach width index (NGVD to monument) reduced 10 m Maximum dune height revised to the Maximum height at or seaward of the original monument position
1999	Amend: (a) Monument to maximum dune height reduced 10 m (b) Beach width index (NGVD to monument) reduced 10 m (c) Maximum dune height revised to the Maximum height at or seaward of the original monument position

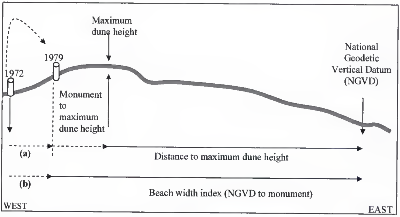

Figure 4-10. Profile revision diagram, monument moved seaward (to east)

Table 4-7. Sample data changes for seaward (east) relocation of monument

1972	Amend: Monument to maximum dune height reduced 10 m Beach width index (NGVD to monument) reduced 10 m Maximum dune height revised to the maximum height seaward of the repositioned monument position
1979-Monument relocated seaward (east) 10 m	
1986	1986 data are unchanged
1999	1999 data are unchanged

Monument data are provided in State Plane NAD 29 and was converted to NAD 83 to be consistent with the projections of the DOQQ's and land use data in the GIS. Appendix E shows the Brevard and St. Johns County monument position and profile details.

Development Variables

The future land use, units per hectare and percent of impervious areas adjacent to the profiles are obtained using aerial photography and GIS. The exact location of the monument and Northing and Easting State Plane coordinates are plotted on the aerials for each site. The photographs show 400 m inland on average, and where the barrier island is narrow, this inland extent will also show the sound or river. A 9-ha area centered at the monument is used to determine the uses and impervious areas immediately adjacent to the monument. The centerline, or meridian of the 9-ha sample area is centered at the monument.

The physical extent of development, defined as any building or impervious area, defines the seaward extent of the sample area. For example, if buildings exist closer to the beach than the monument is located, the sample area is aligned with the seaward extent of development. This may be the case when the monument is located in the dunes beyond and landward of development. The seaward extent of the sample area may extend beyond the monument. This extent is determined by the most recent time period. The 9-ha square has dimensions of 300 m inland from the monument and 150 m either side of the monument. The appropriateness of

adjacent areas to point or discrete data has been noted in Rahn (2001) and Mossa and McLean (1997). In situations where monuments are placed precisely, the development variables in the 9-ha sample areas will encompass the entire county coastline. However, the irregular spacing and replacement of monuments causes the sample areas to be noncontiguous.

The areas unavailable for development and retained in their natural state, such as the areas west of A1A in Guana River State Park, are excluded in the calculation of units per hectare and percentage impervious area. The Intracoastal Waterway, canals or water bodies are also excluded (Appendix D). Digital orthophotography was used for the Brevard and St. Johns counties in 1997 and 1999 and in the 1970s and 1980s variables were extracted from the 1:1200 aerial photography. This photography and future land use data are analyzed in conjunction with the monument locations using GIS.

Dwelling Units (UN) and Dwelling Units per Hectare (UH)

The number of units variable (UN) and the number of residential dwelling units per hectare (UH) are derived for each monument with a continuous geomorphic record. These variables include units of mobile homes, and multifamily units up to 8 units per building. The number of units is determined from the aerial photography and field investigations. The number of hotel rooms cannot be determined from the photography. Hotels, motels and condominiums are not included in the calculation of units. These structures are included as commercial acreage in the calculation by use. The number of units per hectare does not include any measure of commercial activity.

Figure 4-11 shows that 18 units, in this example single-family residential, were recorded in the 9-ha sample area for a UN of 18. The density is the number of units per hectares of residential land. In this case if there are 3 hectares of residential land the 18 units in 3 ha represents a UH of 6 units per hectare.

Table 4-8. Dependent (human/development) variable details

Dependent Variables	Name
Total Number of Dwelling Units	UN
Density of Dwelling Units per Hectare	UH
Hectares of Impervious Area	IMP
Percentage Impervious Area	PIM
Hectares of Commercial Development (includes Hotels, multi-family over 6 units per structure, offices, port related)	C
Total Potential Units Adopted in Future Land Use Plan	FLU
Total Residential Density Adopted in Future Land Use Plan	FLUD
Total Potential Hectares of Commercial Development Adopted in Future Land Use Plan	FLUC
Temporal Scale	**Name**
Actual	
1972	t1
1986	t2
1999 (1997 Brevard)	t3
Dynamic	
Change from 1972 to 1986	t2-1
Change from 1986 to 1999(1997 Brevard)	t3-2
Change from 1972 to 1986(1997 Brevard)	t3-1

Appendix A contains source and measurement data for each variable.

Impervious Area (IMP) and Percentage Impervious Area (PIM)

The impervious area and percentage impervious area are more complete measures of actual development. Impervious areas impact the ability of the dune to act as a sediment store and aeolian transport (Nordstrom, 1994; Nordstrum and McCluskey, 1985) and prevent the absorption of water in storm events (Hall and Halsey, 1991). This research uses an adopted impervious area assumptions for single-family homes. Stormwater runoff at the coast is a major contributor to non-point source pollution and stormwater permits are required of all development except single-family residential. The permits, issued by the St. Johns River Water Management District in both Brevard County and St. Johns require that runoff be stored on site (Von der Osten, 1993). Local county and municipal regulations mirror the requirement. The standard is that the first 2.5 cm must be retained on site and the volume of runoff from a site must be no greater than the runoff before development. The area of each structure and associated

impervious area, such as parking facilities, is calculated from the aerial photography using GIS. The number of single-family units is converted to a standard impervious area. Florida Stormwater Management professionals recognize 213.7 m^2 per unit and 92.9 m^2 per mobile home as an estimate of impervious area, including buildings and driveways in the calculation of fees (Sumwashe, 2000). In Brevard County the established Stormwater Management Utility uses 232.3 m^2 as a proxy for the impervious area for each single-family unit. The total recorded impervious (IMP) area is converted to a percentage of the 9-ha area available for development (PIM) adjacent to each monument.

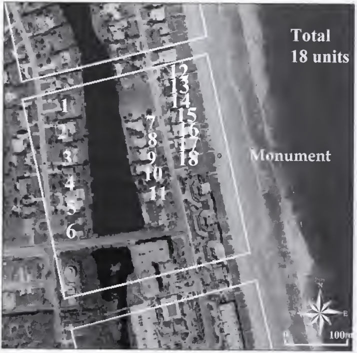

Figure 4-11. Determination of total units (UN) in 9-ha sample area

The use of the Stormwater management accepted single-family impervious area is evaluated using GIS. The total area for each 9-ha sample area was compared to the amount of impervious are that was estimated using the impervious area factor to evaluate the validity of the estimated impervious area for single-family home sizes. In Ponte Vedra, in St. Johns County, it is noted that original single-family structures present in the 1972 photography have been expanded or replaced, resulting in an enlarged impervious area footprint. Conversely structures constructed since the establishment of the Federal Emergency Management Agency FIRM maps in designated "V" zones, must be elevated. The increased cost of construction for elevation of structures also limits the impervious footprint. In Brevard County the existing single-family lot sizes in Cocoa Beach west of Highway A1A, are small (less that 0.1 ha) and expansion of residential structures, when constrained by lot size will be vertical and not impact the total impervious area.

Future Land Use (FLU, FLUD, FLUC)

Land use designations are available from the adopted county Comprehensive Plans. The comprehensive plans for each time period contain future land use designations for the entire County. The amount of each land use category in the area immediately adjacent to the monument is determined using the existing land use maps and GIS and converted to units per hectare for each 9-ha area.

Table 4-9. Land use data availability by study area

Study Area	Data Availability
Brevard County	1972 (adopted 1981)($FLUD_{t1}$), 1989 (not available)
	2000 (2010 horizon) (FLU_{t3}, $FLUD_{t3}$, $FLUC_{t3}$)
St. Johns County	1979 ($FLUD_{t1}$), 1989 (FLU_{t2}, $FLUD_{t2}$, $FLUC_{t2}$)
	2001 (2015 horizon) (FLU_{t3}, $FLUD_{t3}$, $FLUC_{t3}$)

The future land use designations in the first comprehensive plans adopted in the 1970's are general and did not specify future land uses in sufficient detail for distinctions along the coast. In 1972 Brevard County adopted an open space plan (Brevard County Planning Department, 1972) through a 1995 planning horizon, that was incorporated in the 1981 general future land use maps

for Brevard County (Brevard County Board of County Commissioners, 1981). Brevard County has five incorporated coastal municipalities and Patrick Air Force Base. The 1981 Comprehensive plan included land use designations for all incorporated areas and was used to determine the $FLUD_{t1}$ Digital land use data from the 1988 plan (Brevard County Comprehensive Planning Division, 1989) was not available for Brevard County. Digital information for the most recent comprehensive plans was obtained from Brevard County, Cape Canaveral, Cocoa Beach, Satellite Beach and Melbourne (FLU_{t3}, $FLUD_{t3}$ and $FLUC_{t3}$). Indiatlantic is a small coastal municipality and data were not obtained because it contained no monuments with continuous geomorphic data.

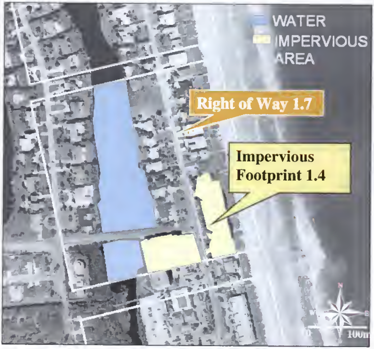

Figure 4-12. Determination of total impervious area (IMP) in 9-ha sample area

The 1979 plan for St. Johns County contained detail from which a density ($FLUD_{t1}$) was determined. Recent adopted plans have land use assigned to each parcel of property. In St. Johns County digital existing land use was produced digitally in 1996 and contained less than 8.1 hectares of land on the coast with a revised land use designations from the 1990 Comprehensive plan (Tim Brown, St. Johns County Planner, personal communication, 2001). These data were used to determine the FLU_{t2}, $FLUD_{t2}$ and $FLUC_{t2}$. In St. Johns County there is one incorporated coastal municipality, St. Augustine Beach. Digital data were obtained for the 2001 comprehensive plan. The individual areas of future land use categories are calculated using GIS. A range of units is traditionally provided for planning residential land use categories. The midpoint of residential land use densities is used for this research. Commercial uses included offices, tourist related uses, hotels, port commercial and retail. Public facilities uses were not included in the commercial designation. Areas designated for future open space, recreation or conservation used were not included as developable and removed from the total hectares available. Figure 4-13 shows 5.49 hectares of low/medium residential land use and 0.36 hectares of high-density residential land use. The mid point of the low/medium residential density is 4 du/ha allowing 22 potential units. The mid point of the high residential density land use is 10 du/ha, which results in 4 potential units, for a sample area total of 26 units. When divided by the total residential hectares, the resulting density is 26 units in 5.9 hectares, or 4.4 du/ha (Figure 4-14)

Application of Variables in Hypotheses

Hypothesis 1: Local geomorphology impacts human variables at the same interval

Hypothesis 1a: The local geomorphology influences the actual development. This hypothesis is illustrated by a relationship between actual geomorphology, and the human variables at that time (Conway and Nordstrom, 2003; McMichael, 1977; Miller, 1980). Examples of the hypothetical relationships between the 1972 geomorphology and the 1972 human variables are shown below. The hypotheses would be the same for the two other discrete time periods.

Table 4-10. Hypothesis 1a, actual geomorphic and human variable relationships.

Actual Geomorphology (Each Time Period)	Hypothetical Relationship	Human Variable (Same Time Period)
1972		1972
Beach Width Index (BW_{t1}); Dune Height (DH_{t1}); Distance Monument to Maximum Dune Height (MDH_{t1}); Distance NGVD to Maximum Dune Height ($DHBW_{t1}$)	Positive	Impervious Area, (IMP_{t1}), Percent Impervious Area (PIM_{t1}) Number of Dwelling Units (UN_{t1}), Dwelling Units per Hectare (UH_{t1}), Commercial Hectares (C_{t1})
Long Term Shoreline Change (LT)	Positive	Impervious Area, (IMP_{t1}-IMP_{t3}), Percent Impervious Area (PIM_{t1}-PIM_{t3}) Number of Dwelling Units (UN_{t1}- UN_{t3}), Dwelling Units per Hectare (UH_{t1}- UH_{t3}), Commercial Hectares (C_{t1}- C_{t3})

Hypothesis 1b: The local geomorphology influences the land use control decision-making. This hypothesis proposes that future land use plans are developed by considering geomorphological conditions (Hails, 1977). The hypothetical relationships between the 1999 geomorphology in St. Johns County and the 2001 proposed future land uses for the 2015 horizon are shown below. The hypotheses would be the same for the two other discrete time periods.

Table 4-11. Hypothesis 1b, actual geomorphic and future land use variable relationships.

Actual Geomorphology (Each Time Period)	Hypothetical Relationship	Land Use Control Variable (Adopted For Each Time Period)
1999		2001
Beach Width Index (BW_{t3}); Dune Height (DH_{t3}); Distance Monument to Maximum Dune Height (MDH_{t3}); Distance NGVD to Maximum Dune Height ($DHBW_{t3}$)	Positive	Future Land Use total units and density (2015 horizon) (FLU_{t3}), ($FLUD_{t3}$)
Long Term Shoreline Change (LT)	Positive	Future Land Use Density (FLU_{t2}, FLU_{t3}), ($FLUD_{t1}$-$FLUD_{t3}$)

Hypothesis 2: The dynamic geomorphology impacts human variables

Hypothesis 2a: The dynamic geomorphology indicators influence the actual human variables. Local coastal geomorphology that varied over decades indicating a dynamic area would be negatively correlated to human variables (Lundberg and Handegard, 1996; McMichael,

1977; Miller, 1980). The example below shows that the smaller the change in geomorphic variable from one time period to another, the more suitable for higher levels of human development or hypothetically a positive relationship. Also the larger the geomorphological factor variable the more suitable for more intense human development (number of dwelling units, impervious area). A low factor value represents a large difference in the net and total change and so a dynamic area. A negative factor value indicates a lower dune or decreasing beach width, for example.

Table 4-12. Hypothesis 2a, dynamic geomorphic and human variable relationships.

Dynamic Geomorphology (Over Entire Period)	Hypothetical Relationship	Human Variable (Change Over Period)
Change in Beach Width Index (BW_{t2-1}, BW_{t3-2}, BW_{t3-1}, BW_{tot}); Change in Dune Height (DH_{t2-1}, DH_{t3-2}, DH_{t3-1} DH_{tot}); Change in Distance Monument to Maximum Dune Height (MDH_{t2-1}, MDH_{t3-2}, MDH_{3-1} MDH_{tot}); Change in Distance NGVD to Maximum Dune Height ($DHBW_{t2-1}$, $DHBW_{t3-2}$, $DHBW_{3-1}$, $DHBW_{tot}$);	Negative	Impervious Area, (IMP_{t1}-IMP_{t3}), Percent Impervious Area (PIM_{t1}-PIM_{t3}) Number of Dwelling Units (UN_{t1}- UN_{t3}), Dwelling Units per Hectare (UH_{t1}- Uh_{t3}), Commercial Hectares (C_{t1}- C_{t3})
Factor Variable Beach Width Index Factor, (BW_f); Dune Height Factor, (DH_f); Distance Monument to Maximum Dune Height Factor (MDH_f); Distance NGVD to Maximum Dune Height Factor ($DHBW_f$)	Positive	Impervious Area, (IMP_{t1}-IMP_{t3}), Percent Impervious Area (PIM_{t1}-PIM_{t3}) Number of Dwelling Units (UN_{t1}- UN_{t3}), Dwelling Units per Hectare (UH_{t1}- UH_{t3}), Commercial Hectares (C_{t1}- C_{t3})

Hypothesis 2b: The dynamic geomorphology indicators influence the land use control decision-making. This hypothesis proposes an adaptation of Bush and others (1999) with future land use outcomes as the result of the characteristics of the physical environment. The example below shows that the smaller the change in geomorphic variable from one time period to another, the more suitable for higher adopted future total units and densities. Also the larger the geomorphological factor variable the more suitable for higher adopted future total units and densities.

Table 4-13. Hypothesis 2b, dynamic geomorphic and future land use relationships.

Dynamic Geomorphology (Over Entire Period)	Hypothetical Relationship	Land Use Control Variable
Change in Beach Width Index (BW_{t2-1}, BW_{t3-2}, BW_{t3-1}, BW_{tot}); Change in Dune Height (DH_{t2-1}, DH_{t3-2}, DH_{t3-1} DH_{tot}); Change in Distance Monument to Maximum Dune Height (MDH_{t2-1}, MDH_{t3-2}, MDH_{3-1} MDH_{tot}); Change in Distance NGVD to Maximum Dune Height ($DHBW_{t2-1}$, $DHBW_{t3-2}$, $DHBW_{3-1}$, $DHBW_{tot}$);	Negative	Future Land Use Density (FLU_{t2}, FLU_{t3}), ($FLUD_{t1}$- $FLUD_{t3}$)
Factor Variable Beach Width Index Factor, (BW_f); Dune Height Factor, (DH_f); Distance Monument to Maximum Dune Height Factor (MDH_f); Distance NGVD to Maximum Dune Height Factor ($DHBW_f$)	Positive	Future Land Use Density ($FLUD_{t1}$- $FLUD_{t3}$)

Hypothesis 3: There are temporally lagged relationships between the actual and dynamic geomorphology variables and the human variables. This hypothesis contemplates that geomorphology in one time period will influence human variables in later time periods (Nordstrom, 1987; Van Der Wal, 2004). The example below shows a positive relationship between the dune height in 1972 and the human variables in later time periods. The second example shows the wider the beach width in 1986 the more stable the coastal environment and therefore the more suitable for greater a impervious area and dwelling units in the later time period.

Hypothesis 4: The dependent variables will have different relationships with the independent variables in the two separate study areas. The explanatory power of the individual variables will be different in each part of the coastline (Byrnes et al., 1995). For example, the dune height in Brevard County will not have the same relationships with the human variables are the dune height in St. Johns County. The regression coefficients and significant variables for each county will be different.

Table 4-14. Hypothesis 3, lagged geomorphic and human variable relationships.

Actual Geomorphology (For 3 Time Periods)	Hypothetical Relationship	Lagged Land Use Control Variable
1972 Dune Height (DH_{t1})	Relationship with variable in later time period	2015 Future Land Use Density (FLU_{t3}, $FLUD_{t3}$), 1986 and 1999 Impervious Area, (IMP_{t2}, IMP_{t3}), 1986 and 1999 Percent Impervious Area (PIM_{t2}, PIMt3,) 1986 and 1999 Number of Dwelling Units (UN_{t2}, UN_{t3}), 1986 and 1999 Dwelling Units per Hectare (UH_{t2}, UH_{t3}), 1986 and 1999 Commercial Hectares (C_{t2}, C_{t3})
1986 Beach Width Index (BW_{t2})	Relationship with variable in later time period	1999 Impervious Area, (IMP_{t3}), 1999 Percent Impervious Area (PIM_{t3}) 1999 Number of Dwelling Units (UN_{t3}), 1999 Dwelling Units per Hectare (UH_{t3}), 1999 Commercial Hectares (C_{t3})

Table 4-15. Hypothesis 4, variable interactions by jurisdiction

Actual Geomorphology (For 3 Time Periods)	Hypothetical Relationship	Land Use Control Variable of that County
Brevard County Dune Height (DH_{t2-1}-DH_{t3-1})	Varies-different from St. Johns County	Brevard County Future Land Use Density (FLU_{t2}, FLU_{t3}), ($FLUD_{t1}$-$FLUD_{t3}$) Brevard County Impervious Area, (IMP_{t1}-IMP_{t3}), Brevard County Percent Impervious Area (PIM_{t1}-PIM_{t3}) Brevard County Number of Dwelling Units (UN_{t1}- UN_{t3}), Brevard County Dwelling Units per Hectare (UH_{t1}-UH_{t3}), Brevard County Commercial Hectares (C_{t1}.C_{t3})
St. Johns County Dune Height (DH_{t2-1}-DH_{t3-1})	Varies-different from Brevard County	St. Johns County Future Land Use Density (FLU_{t2}, FLU_{t3}), ($FLUD_{t1}$-$FLUD_{t3}$) St. Johns County Impervious Area, (IMP_{t1}-IMP_{t3}), St. Johns County Percent Impervious Area (PIM_{t1}-PIM_{t3}) St. Johns County Number of Dwelling Units (UN_{t1}- UN_{t3}), St. Johns County Dwelling Units per Hectare (UH_{t1}-UH_{t3}), St. Johns County Commercial Hectares (C_{t1}.C_{t3})

Data Analyses

The 34 dependent and 43 independent variables were assembled in a database for analyses. Statistical analyses were performed using the NCSS statistical package. Descriptive statistics for

each variable, for both Brevard and St Johns counties, were developed. The lack of normality noted in the independent geomorphic variables prompted further analysis by geomorphic unit. Brevard County was divided north and south of Patrick Air Force Base, and by orientation. St. Johns County data were divided by geomorphic unit. The county was divided into two areas – Ponte Vedra to Vilano Beach, and Anastasia Island (St. Augustine Beach to Matanzas Inlet). The Summer Haven monuments (199 to 208) south of Matanzas inlet were not included.

The importance of spatial variation of variables along the coast is captured utilizing spatial location of the 9-ha sample areas. The statistical inferences determined by the variables cannot be isolated without consideration of the spatial implications (Burt and Barber, 1996; Fotheringham and Brunsdon, 2004). The variables ACC, DACC, and POS serve as a proxy for location. The variable POS is the distance along the coast from north to south. The influence of the spatial dimension is further expanded by the distance to access (ACC) and direction and distance to access (DACC) variables. These variables are weighted forms of location of the sample area. ACC is a linear measure of the distance north or south, to the closest access or bridge to the barrier island. In northern St. Johns County access is north into the adjacent county. There is no access to the west between the county boundary and the Vilano Beach bridge at St. Augustine Pass. In Brevard County access is limited to causeways to the barrier islands. The DACC variable adds a direction component to the distance to the access point. A negative DACC value represents that the nearest access point is to the south of the monument. The orientation of the seaward axis of the 9-ha sample area to north (OR) is a further spatial derivative to enhance the statistical analyses. St. Johns County is also divided by geomorphic unit into two parts to recognize the importance of separate analyses for geographically distinct areas. Geographically weighted regression can also be considered for the evaluation of variables at varied spatial scales, from global, regional and local (Mei et al., 2004). This research does not consider what has been defined as mixed geographically weighted regression.

Row-wise Spearman Rank Correlations were performed for both St. Johns and Brevard County. This methodology was selected to evaluate the continuous and discrete data. Nominal data includes that presence of renourishment (RN), dune renourishment in Brevard County (RND), structures (SW) and State erosion designation (ER). The Spearman Rank correlation is an indicator of a simple relationship by rank order, so that a positive relationship between variables shows that the highest measure of the independent variable is associated with the highest measure of the dependent variable. This indicator of monotonocity does not distinguish linear from non-linear relationships because the ranked data provide a directional indicator of the variable association but not an indicator of distance between variables. All dependent and independent variables were analyzed.

The non-parametric statistics provide general bivariate comparisons for the direction of variable association. Multiple regression analyses are used to evaluate the multiple interactions of variables and to measure and model the dimensions of the impacts of variables. Independent variables were transformed and integrated (Appendix B). The categorical data, such as the presence of absence of structures and the designation of erosion concern (ER) determined by the Clark (1999) were used as dummy variables for analyses (Appendix B). Other dummy variables include the presence of renourishment (RN), dune renourishment (RND, Brevard County only), and structures (SW). This portion of the data analyses enables the use of the ordinal variables to be evaluated for interaction with other variables more appropriately than in the non-parametric statistical analyses. A stepwise analysis of each dependent variable was performed. Once the relevant variables were isolated, multiple regression analyses were performed for all the Brevard County sample areas, the entire St. Johns County data and the St. Johns County data by geomorphic area.

Methodology Implications

Both the number of units and density changes are sensitive if the numbers (UN, UH) and available hectares are small. For example in St. Johns County at monument 184 there was a

decrease of 4 units (UN), from 1972 to 1997 with a corresponding increase in impervious area (PIM) increase of over 90 percent. This was due to the small area available for development and the sensitivity of using the percentage of available area. Similarly the methodology is sensitive to data misclassification. When redevelopment occurs and residential areas are converted to other uses, the decrease in units (UN, UH) will be replaced by increased impervious area (IMP, PIM) and hectares of commercial (C). In St. Johns County monument (187) was revised in 1986 after GIS investigation of the percent impervious (PIM), which was over 100, and further GIS investigations showed miscoding of impervious area. This served as a methodological check. In Brevard County at monuments 21 and 35 the PIM was over 100, by less than 1 percent. Further review indicated that in this area small lots with two story single-family structures and the standard residential hectare estimate had overestimated residential impervious area. These areas were adjusted to reflect a limit at 100 percent.

CHAPTER 5
ANALYSES AND RESULTS

The descriptive statistics of the independent and dependent variables for each County are provided in Appendix G. The results of the non-parametric statistical analyses are shown in Appendix H. St. Johns County variable plots of beach width (Figure 5-1) and the variation in long-term shoreline change and independent variables (Appendix I) illustrate the potential for variables to be more appropriately analyzed by smaller geographic unit. St. Johns County was divided into two areas – Ponte Vedra to Vilano Beach, and Anastasia Island (St Augustine Beach to Matanzas Inlet). Appendix I includes the graphic representation of variables by county that are not included in this chapter. The regression analyses and results are shown in Appendix J.

Independent Variable Characteristics

Appendix G contains the independent geomorphic variable descriptive statistic summary. Brevard County data were from 1972 ($_{t1}$), 1986 ($_{t2}$) and 1997 ($_{t3}$). St Johns County data were collected for 1972 ($_{t1}$), 1986 ($_{t2}$) and 1999 ($_{t3}$). The variables are time specific (t1, t2, t3) and dynamic (t2-1, t3-2, and t3-$_1$).

Beach Width (BW)

The Brevard County beach width values of the 9-ha sample areas are normally distributed in 1972 and 1997. The number of monuments with data decreases from 147 points in 1972 to 140 in 1997 indicating monument replacement. The beach is wider between Satellite Beach and Indiatlantic (monuments 110 to 120), in the area south of Cocoa Beach and in southern Brevard County (Table 5-1). Changes in beach width over time are more extreme in northern Brevard County, north of monument 60, particularly adjacent to the Port Canaveral Inlet, where the jetties have influenced accretion. The average beach width is highest in 1986 at 108.5m, but in the same year a minimum beach width of 35.7m was also recorded. The maximum beach width increases

over time from 108.5m in 1986 to 227.2m in 1997. The negative value for mean beach width from 1986 to 1997 of –3.4m illustrates that the beach width on average decreased from 1986 to 1997. The absolute change (BW_{tot}) has a mean of 28.0 m. However the range of BW_{tot} is large, from just over a meter to over 300m. The negative values for the minimum beach width indicate that there are areas where the beach width decreased in each of the time periods. The BW descriptive statistics in Brevard County indicate that there is no simple trend in the geomorphic variable. North of Patrick Air Force Base (monument 60), Brevard County is more dynamic, with more extreme temporal change. The beach is consistently wider in 1986 in Brevard County, south of Patrick Air Force Base. The BW variation, indicated by the range in values, increases over time.

Beaches in St. Johns County (Figure 5-1) are widest and show more variation from 1972 to 1999 on Anastasia Island. Trends are similar to Brevard County, with accretion in 1986 north of St. Augustine Pass. In the Vilano Beach area the 1999 beach width is the most narrow. Beach width rapidly increased at monument 121at the north jetty at St. Augustine pass. Matanzas Inlet has rock revetments adjacent to A1A, but no jetties. The sample areas south of Matanzas Inlet have the narrowest beaches in St. Johns County. The rocks that were adjacent to monument 141 in St. Augustine Beach in 1999 were exposed. In St Johns County BW accretion north of St Augustine Inlet from 1972 to 1986, is similar to Brevard County.

Maximum Dune Height (DH)

The highest point recorded on each of the coastal profiles is the maximum dune height (DH), and this may occur at the monument. In Brevard County the maximum dune height increases southward (Figure 5-2). South of Port Canaveral Inlet in Cocoa Beach the maximum dune height is 3 to 4m, compared to over 6m south of monument 150. The dune heights are most dynamic at Cocoa Beach and Patrick Air Force Base. The average dune height increases from 5.0m in 1972 to 5.1m at 1997 and the DH_{t1} and DH_{t2} are normally distributed (Table 5-2).

Table 5-1. Descriptive statistics, beach width (BW)

	Count	Mean	Standard Deviation	Min.	Max.	Kolmogorov-Smirnov	0.05	Normality
Beach Width (Brevard County)								
BW_{t1}	147	98.8	27.6	41.4	149.9	0.0399	0.073	Accept
BW_{t2}	141	103.6	28.9	35.7	198.7	0.0833	0.074	Reject
BW_{t3}	140	101.8	31.9	40.6	267.8	0.0651	0.075	Accept
BW_{t2-1}	142	5.5	24.1	-149.9	126.6	0.1947	0.074	Reject
BW_{t3-2}	138	-3.4	28.4	-163.8	155.3	0.1968	0.075	Reject
BW_{t3-1}	143	2.2	29.2	-148.5	196.7	0.2090	0.074	Reject
BW_{tot}	138	28.0	39.7	1.2	305.1	0.2589	0.075	Reject
BW_f	138	0.1	0.7	-1	1	0.1200	0.075	Reject
Beach Width (St. Johns, Entire County)								
BW_{t1}	165	79.7	19.6	35.4	140.6	0.1784	0.069	Reject
BW_{t2}	167	95.4	34.8	30.4	202.8	0.2011	0.068	Reject
BW_{t3}	165	86.3	37.6	30.9	198.5	0.2247	0.069	Reject
BW_{t2-1}	164	15.4	20.1	-17.1	80.1	0.1141	0.069	Reject
BW_{t3-2}	165	-9.7	14.8	-65.1	45.4	0.0761	0.069	Reject
BW_{t3-1}	163	5.3	23.0	-55.7	76.1	0.1572	0.069	Reject
BW_{tot}	162	32.8	21.4	2.8	133.2	0.1386	0.069	Reject
BW_f	162	0.01	0.7	-1.0	1.0	0.0966	0.069	Reject
Beach Width (St. Johns, North 1 to 121)								
BW_{t1}	111	71.8	8.3	49.0	99.1	0.0851	0.084	Reject
BW_{t2}	110	81.4	117	58.3	139. 5	0.0680	0.084	Accept
BW_{t3}	110	68.7	12.6	44.9	132.7	0.1008	0.084	Reject
BW_{t2-1}	110	9.7	12.5	-17.1	68.0	0.0809	0.084	Accept
BW_{t3-2}	110	-12.7	13.4	-65.1	45.4	0.1303	0.084	Reject
BW_{t3-1}	110	-2.9	12.6	-29.4	35.2	0.0870	0.084	Reject
BW_{tot}	110	27.8	17.7	2.8	133.2	0.1282	0.084	Reject
BW_f	110	-0.2	0.6	-1.0	1.0	0.0833	0.084	Accept
Beach Width (St. Johns, Anastasia Island, 141 to 195)								
BW_{t1}	43	106.1	16.2	62.7	140.6	0.0759	0.134	Accept
BW_{t2}	46	140.4	31.5	49.4	202.8	0.0645	0.129	Accept
BW_{t3}	46	136.6	32.5	63.9	198.5	0.0645	0.129	Accept
BW_{t2-1}	43	35.9	22.2	-10.7	80.1	0.0634	0.134	Accept
BW_{t3-2}	46	-3.8	17.2	-50.5	36.0	0.0862	0.129	Accept
BW_{t3-1}	43	31.2	24.8	-42.3	76.1	0.0996	0.134	Accept
BW_{tot}	43	49.7	22.0	11.7	102.2	0.0940	0.134	Accept
BW_f	43	0.6	0.5	-1.0	1.0	0.2310	0.134	Reject

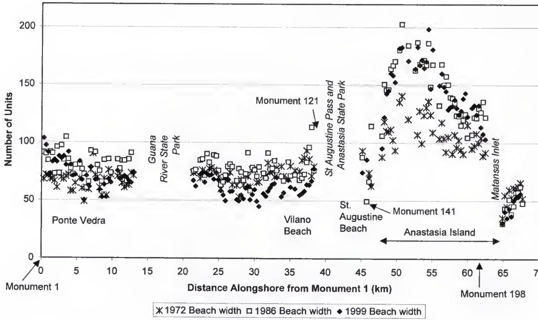

Figure 5-1. St. Johns County beach width variations, 1972-1999, (BW_{t1}, BW_{t2}, BW_{t3})

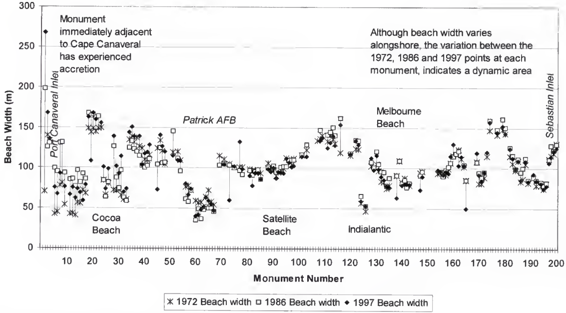

Figure 5-2. Brevard County beach width variations, with trend 1972-1997, (BW_{t1}, BW_{t2}, BW_{t3})

Table 5-2. Descriptive Statistics, maximum dune height (DH)

	Count	Mean	Standard Deviation	Min.	Max.	Kolmogorov-Smirnov	0.05	Normality
Maximum Dune Height (Brevard County)								
DH_{t1}	136	5.0	1.0	2.6	7.2	0.0623	0.076	Accept
DH_{t2}	131	5.0	1.0	3.0	7.3	0.0559	0.077	Accept
DH_{t3}	131	5.1	0.9	3.0	7.4	0.0781	0.077	Reject
DH_{t2-1}	129	0.01	0.7	-5.6	3.3	0.1874	0.078	Reject
DH_{t3-2}	128	0.2	1.0	-2.3	6.8	0.2959	0.078	Reject
DH_{t3-1}	125	0.1	0.4	-1.4	1.4	0.0875	0.079	Reject
DH_{tot}	125	0.7	1.2	0	10.9	0.2851	0.079	Reject
DH_f	121	0.2	0.7	-1	1	0.1625	0.079	Reject
Maximum Dune Height (St. Johns, Entire County)								
DH_{t1}	170	5.5	2.0	2.6	10.3	0.0922	0.068	Reject
DH_{t2}	169	5.6	1.8	3.0	10.2	0.1172	0.068	Reject
DH_{t3}	169	5.8	2.0	3.0	10.2	0.0998	0.068	Reject
DH_{t2-1}	170	0.1	1.3	-6.35	8.1	0.2879	0.068	Reject
DH_{t3-2}	170	0.2	1.1	-5.00	9.1	0.2569	0.068	Reject
DH_{t3-1}	170	0.3	1.6	-6.4	9.1	0.2572	0.068	Reject
DH_{tot}	170	0.9	1.5	0.02	9.1	0.2731	0.068	Reject
DH_f	170	0.1	0.8	-1.0	1.0	0.1816	0.068	Reject
Maximum Dune Height (St. Johns, North, 1 to 121)								
DH_{t1}	111	5.8	1.8	3.3	10.3	0.1017	0.084	Reject
DH_{t2}	110	5.8	1.8	3.3	10.2	0.1324	0.084	Reject
DH_{t3}	110	5.9	2.0	3.2	10.2	0.1451	0.084	Reject
DH_{t2-1}	111	-0.03	0.7	-6.4	1.8	0.3150	0.084	Reject
DH_{t3-2}	111	0.2	0.9	-1.0	9.1	0.2898	0.084	Reject
DH_{t3-1}	111	0.1	1.2	-6.4	9.1	0.2729	0.084	Reject
DH_{tot}	111	0.5	1.1	0.02	9.1	0.3152	0.084	Reject
DH_f	111	0.0	0.8	-1.0	1.0	0.1728	0.084	Reject

Table 5-3. Descriptive Statistics, maximum dune height (DH), Anastasia Island

	Count	Mean	Standard Deviation	Min.	Max.	Kolmogorov-Smirnov	0.05	Normality
Maximum Dune Height (St. Johns, Anastasia Island, 141 to 195)								
DH_{t1}	48	5.1	2.4	2.6	9.6	0.1078	0.127	Accept
DH_{t2}	48	5.5	1.8	3.0	9.5	0.0906	0.127	Accept
DH_{t3}	48	5.9	1.7	3.0	9.5	0.0764	0.127	Accept
DH_{t2-1}	48	0.4	2.1	-5.0	8.1	0.2930	0.127	Reject
DH_{t3-2}	48	0.4	0.9	-2.7	2.4	0.1630	0.127	Reject
DH_{t3-1}	48	0.8	2.1	-5.0	6.9	0.1670	0.127	Reject
DH_{tot}	48	1.7	2.0	0.1	9.5	0.1848	0.127	Reject
DH_f	48	0.3	0.8	-1.0	1.0	0.1961	0.127	Reject

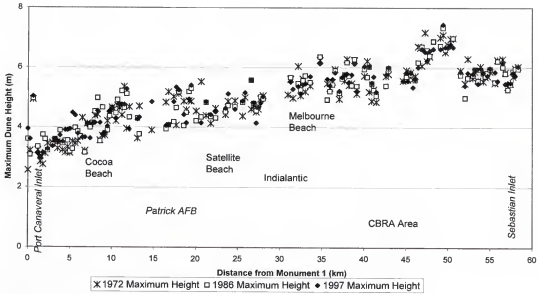

Figure 5-3. Brevard County maximum dune height variations, 1972-1997 (DH_{t1}, DH_{t2}, DH_{t3})

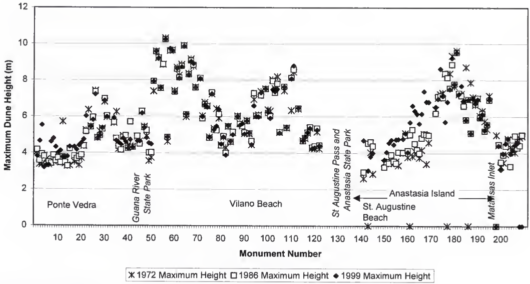

Figure 5-4. St. Johns County maximum dune height variations with trend, 1972-1999 (DH_{t1}, DH_{t2}, DH_{t3})

In St. Johns County, dune height variations are more pronounced than in Brevard County. Dunes are higher on average and increase in average maximum height from 5.5m in 1972 to 5.8m in 1999. Maximum dune heights are lowest in Ponte Vedra and at St. Augustine Beach. Historically the dunes in Ponte Vedra were removed to ensure adequate views of the ocean. Maximum dune heights increase from 1972 to 1999. From monument 35 to 121, dune heights have been stable. The low dune heights at St. Augustine Beach are a function of erosion and placement of rock revetments at the coast. This area and the area to the north in Anastasia State Park have been subject to overwash and dunes are limited. Although dune height varies spatially, in northern St. Johns County, temporally there has been very little change in maximum dune height. The positive value of 0.1 for the Dune Height Factor (DH_f), which is a measure of the total over net change, shows that an overall increase in height, but the closer this factor is to zero the larger the difference in net and total changes demonstrating dynamic change over time. The DH in northern St. Johns County and Anastasia Island are very similar, increasing from 1972 to 1999, but Anastasia Island is normally distributed. Northern St. Johns County experienced a large increase from 1986 to 1999, whereas Anastasia Island dune height increases are consistent in both 1972 to 1986 and 1986 to 1999.

Monument to Maximum Dune Height (MDH)

The descriptive statistics and spatial display for this variable are presented in Appendix G and Appendix I. Actual MDH values are not necessarily an indicator of a wide or narrow dune field. A high MDH value may represent a wide stretch of dunes, or a monument placed further inland. However, changes between time periods are a measure of the geomorphic stability of the dunes in relation to a stationary point, the monument. An increase in the MDH over time represents a seaward movement of the maximum dune height. Without an indication of beach width the seaward movement of maximum height is assumed to indicate erosion, because the highest point on the profile is now more seaward. The landward movement of the MDH is hypothesized as indicating a prograding dune field. This variable is important in the evaluation of

the impact of impervious areas and structures on the function of the dunes. In Brevard County, similar to dune height, the highest variation occurs adjacent to Cocoa Beach and Satellite Beach. The average MDH decreases from 1972 to 1997, with value of –2.1m, showing the maximum height moved closer to the monument, or inland. The $MDHt3_{-1}$ moved seaward of the monument.

The maximum dune height has moved seaward in northern St. Johns County, and on Anastasia Island, indicated by a reduction in the MDH, or distance from the monument to the position of the maximum dune height (Appendix I). Between monuments 60 and 90 the dune field may be described as stable, with small changes between 1972 and 1986, 1986 and 1999, and 1972 and 1999. Monuments 90 to 121 have migrated landward with lower MDH from 1972 to 1999. Similarly in Summer Haven the maximum dune height has moved inland, possibly due to aggressive sand fencing by property owners noted by Foster (2002). The average MDH increases countywide as the maximum dune height moves seaward, although the total seaward movement is only 2.3m in northern St. Johns County, compared to 16.35m on Anastasia Island.

Maximum Dune Height to NGVD (DHBW)

The descriptive statistics and spatial display for this variable are presented in Appendix G and Appendix I. The maximum dune height to NGVD is a measure of beach width bounded by geomorphic characteristics. This variable is sensitive to the location of the maximum dune height and dune renourishment or sand fencing will impact the resulting DHBW value. In Brevard County this index shows that the wider and more dynamic areas are adjacent to Cocoa Beach. Satellite Beach is also more dynamic than adjacent areas. The profiles with large changes from 1972 to 1997 are also those with the largest increase in 1986. South of Indiatlantic, with the exception of a few areas that experienced extreme beach width increases in conjunction with landward movements of the maximum dune height, the area has seen only small changes. The range increase over time (Appendix G) indicates increasing extremes with areas changing more than in previous time periods. The pattern of beach width decrease from 1986 to 1997 (BW_{t3-2}) is also reflected in this variable, showing the beach width decreased in conjunction with the seaward

movement of the maximum dune height. However the average Brevard County DHBW returns to 49.9m in 1997 from a 1972 measurement of 49.2m.

The 1999 DHBW in St. Johns County is similar to 1972, and lower in certain areas. The average beach width for the entire county does not recede back to the 1972 width, as it does in Brevard County. Although the maximum dune height (DH) moved seaward in 1986, the DHBW was wider. In northern St. Johns County the DHBW is narrowest in 1999 (63.8m) and widest in 1986 (77.7m), which is consistent with the BW_{t2} and BW_{t3}. On Anastasia Island the DHBW is also widest in 1986 at over 125m, but the decrease in 1999 is not to the extent of the level in 1972. Summer Haven has seen a consistent decline in the DHBW from 1972 to 1999.

Long Term Change (LT)

The long-term changes show variations (Chapter 4, figures 4-3 and 4-4) with the highest accretion of over 1.3m/yr occurs adjacent to Port Canaveral Inlet and in Cocoa Beach. South of Satellite beach there is one area of Brevard County experiencing long-term erosion, between monuments 154 and 163. The average long-term change in Brevard County is 0.3m/yr (Table 5-4) and is an indicator of a coastal area behaving as a single geomorphic unit.

The average long-term change for all monuments in St. Johns County is 0.13m/yr. Table 5-4 shows why consideration of St. Johns County by geomorphic unit is important. Northern St. Johns County and Anastasia Island have distinctly different patterns of long-term change. Northern St. Johns County is predominantly stable with areas of small long-term erosion at Ponte Vedra and Vilano Beach. Rapid accretion is occurring at monument 122, adjacent to St. Augustine Pass. Anastasia Island varies from severe erosion of over 7m/yr at St. Augustine Beach to long-term accretion of over 2 m/yr in central Anastasia Island. The Sea Haven area, south of Matanzas Inlet is experiencing erosion. Anastasia Park is not included in this research because its status precludes development potential. However, the area south of St Augustine Pass with long-term erosion problems was renourished in 2002 and 2003.

Table 5-4. Descriptive statistics, long-term change (LT), orientation (OR) and monument position from north (POS), distance to access (ACC) and distance and direction to access (DACC)

	Count	Mean	Standard Deviation	Min.	Max.	Kolmogorov-Smirnov	0.05	Normality
Brevard County								
LT	137	0.3	0.4	-0.2	1.51	0.2260	0.075	Reject
OR	125	168.6	13.6	152.0	195.0	0.1882	0.079	Reject
POS	138	28.9	17.8	0.0	58.3	0.1048	0.075	Reject
ACC	138	6.4	6.3	0	22.4	0.1952	0.075	Reject
DACC	138	-4.7	7.6	-22.4	7.9	0.1347	0.075	Reject
St. Johns, Entire County								
LT	164	0.1	1.1	-7.3	2.4	0.2504	0.069	Reject
OR	168	167.0	4.8	153.0	183.0	0.1652	0.068	Reject
POS	136	34.7	21.2	0.0	67.7	0.1048	0.076	Reject
ACC	136	6.6	4.4	0.0	16.9	0.0904	0.076	Reject
DACC	136	0.1	7.9	-13.0	16.9	0.0929	0.076	Reject
St. Johns, North, Ponte Vedra to Vilano Beach, monuments 1 to 121								
LT	110	-0.1	0.3	-0.5	2.0	0.2446	0.084	Reject
OR	110	167.3	2.4	157.0	171.0	0.2662	0.084	Reject
POS	81	19.6	12.5	0.0	38.3	0.1337	0.098	Reject
ACC	81	7.7	4.7	0.0	16.9	0.0721	0.098	Accept
DACC	81	2.2	8.8	-13.0	16.9	0.0678	0.098	Accept
St. Johns, Anastasia Island, monuments 141 to 195								
LT	45	0.8	1.9	-7.3	2.4	0.2224	0.131	Reject
OR	47	167.2	8.1	155.0	183.0	0.1624	0.128	Reject
POS	44	54.7	5.1	44.8	62.5	0.0806	0.132	Accept
ACC	44	3.5	1.9	0.0	7.3	0.0710	0.132	Accept
DACC	44	-1.2	3.8	-6.5	7.3	0.1285	0.132	Accept

Access (ACC, DACC) Variables

The average distance to access to the mainland in Brevard County is 6.4km and the sample area furthest from access is 22.4km (Table 5-4). The negative value for the DACC average indicates more access in the north part of the study area. The average distance to access to the mainland in St. Johns County is 6.6km and the sample area furthest from access is 16.9km. The value for the DACC average is close to zero, indicating that that the direction to the nearest access point is as likely to be north as south. When separated by geomorphic unit, however, it is further to access points from northern St. Johns County (7.7km) than on Anastasia Island (3.5km).

Dependent Variables Characteristics

The dependent variables were collected over the same three time periods as the independent variables. Brevard County data were from 1972 (t1), 1986 (t2) and 1997 (t3). St Johns County data were collected for 1972 (t1), 1986 (t2) and 1999 (t3). Future land use data were collected from 1972 (t1), and 2000 (t3) plans for Brevard County and 1979 (t1) 1989 (t2) and 2001 (t3), plans for St Johns County (Appendix B).

Number of Dwelling Units (UN)

The number of dwelling units variable represents the total units (in structures containing 8 units or less) present in the 9-ha sample areas in Brevard and St. Johns County. Figure 5-3 shows the number of units for each time period and the potential units permitted by the FLU_{t3}. Cocoa Beach, Satellite and Melbourne Beach have higher existing units and proposed future land uses than the rest of coastal Brevard County. In southern Brevard County there are lower densities and lower proposed future land use densities. The average number of dwelling units increases from 17.7 in 1972 to a 28.1 in 1997 for the 138 9-ha sample areas (Appendix G) increasing by 10.4 units. The minimum number of units for each time period ($_{t1}$ to $_{t3}$) is zero, indicating there were 9-ha sample areas without units. The $_{t2\text{-}1}$ to $_{t3\text{-}1}$ data shows negative values, indicating that there were sample areas that experienced a decrease in the number of units. The decrease in the number of dwelling units was caused by demolitions, reconstruction, density increases and the removal of mobile homes (monument 143). Similarly, conversion to higher density structures affects this variable. Structures with over 8 units were included in the impervious area variable. The renovation of Patrick Air Force Base impacted the number of units and density. The $UN_{t3\text{-}2}$ data reflects the removal of Base housing and replacement at lower densities.

The average number of dwelling units increases from 7.2 in 1972 to 17.8 in 1999 for the 138 9-ha sample areas in St. Johns County (Appendix G), a mean increase of 10.6 units. The standard deviations recorded for 1972 to 1999 are 10.2 to 19.6, indicating that by 1999 there was a greater range in the number of dwelling units by sample area. Some 9-ha sample areas

contained no units and others (monuments 94, 150 and 160) experienced a decrease in the number of units caused by demolitions and renovations in Ponte Vedra (monuments 15 to 27), and the removal of mobile home parks (monument 150). Areas of former mobile home parks, when replaced with single-family homes result in lower densities, and when replaced with multifamily (greater than 8 units per building) or commercial, higher impervious areas.

Descriptive statistical for the two geomorphic units in St. Johns County, north and south of the St. Augustine Inlet (Appendix G) show that in the north part of St. Johns County from Ponte Vedra to Vilano Beach the average number of dwelling units increases from 5.6 in 1972 to 15.5 in 1999 for the 83 9-ha sample areas. The a mean increase of 9.9 units which was lower than the countywide increase of 10.6 dwellings. In the south part of St. Johns County, known as Anastasia Island, from St Augustine Beach to Matanzas Inlet, dwelling units increases from 11.5 in 1972 to 24.9 in 1999 for the 44 9-ha sample areas. The standard increased from 12.5 to 25.9, indicating that by 1999 there was a greater range in the number of dwelling units by sample area. Anastasia Island has a higher average dwelling unit count per 9-ha sample area than the countywide average for each time period.

Dwelling Units per Hectare (UH)

The dwelling units per hectare variable is a measure of residential density. It is the ratio of the number of units in each 9-ha sample area to the hectares available for development. The hectares unavailable for development include water bodies, conservation areas and parks. Brevard County residential density increases from 3.2 du/ha in 1972 to 5.0 du/ha in 1997 for the 138 9-ha sample areas (Table 5-5). In Brevard County decreased density occurred where the single-family units were converted to buildings with greater than 8 units, and land that was removed from availability for development. The Brevard County Park System was funded by a sales tax 1986, and had a goal of coastal property acquisition reducing the total available hectares in the density calculation. Increases in residential density are consistent with the total number of units (UN) unless the available area decreased.

contained no units and others (monuments 94, 150 and 160) experienced a decrease in the number of units caused by demolitions and renovations in Ponte Vedra (monuments 15 to 27), and the removal of mobile home parks (monument 150). Areas of former mobile home parks, when replaced with single-family homes result in lower densities, and when replaced with multifamily (greater than 8 units per building) or commercial, higher impervious areas.

Descriptive statistical for the two geomorphic units in St. Johns County, north and south of the St. Augustine Inlet (Appendix G) show that in the north part of St. Johns County from Ponte Vedra to Vilano Beach the average number of dwelling units increases from 5.6 in 1972 to 15.5 in 1999 for the 83 9-ha sample areas. The a mean increase of 9.9 units which was lower than the countywide increase of 10.6 dwellings. In the south part of St. Johns County, known as Anastasia Island, from St Augustine Beach to Matanzas Inlet, dwelling units increases from 11.5 in 1972 to 24.9 in 1999 for the 44 9-ha sample areas. The standard increased from 12.5 to 25.9, indicating that by 1999 there was a greater range in the number of dwelling units by sample area. Anastasia Island has a higher average dwelling unit count per 9-ha sample area than the countywide average for each time period.

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The density of dwelling units increases from 1.4 in 1972 to 3.5 in 1999 for the 138 9-ha sample areas in St. Johns County (Table 5-5). Increasing by 2.1 units per hectare. Decreases in the number of dwelling units were caused by demolitions and renovations in Ponte Vedra (monuments 15 to 27), and the removal of mobile home parks at St. Augustine Beach. When divided by geomorphic unit the descriptive statistics do not reflect spatial differences in residential density. St. Johns County from Ponte Vedra to Vilano Beach has a density increases from 1.4 in 1972 to 3.5 in 1999 for the 83 9-ha sample areas. Anastasia Island from St Augustine Beach to Matanzas Inlet has average density increases from 1.7 units per hectare in 1972 to 3.7 in 1999 in the 44 9-ha sample areas.

Future Land Use Variables (FLU, FLUD)

The number of units existing in each of the time periods is shown with the FLU_{t3} in Figures 5-3 and 5-4. Apart from the CBRA area, the trend is that number of units increases from 1972 to 1999 and that the future land use plan (FLU_{t3}) permits higher units than the 1999 record. The CBRA area was intentionally proposed with lower future land use densities than exist to reflect that the designation does not permit use Federal funding for future development (Mel Scott, Brevard County Growth Management, personal communication, 2003). Brevard County prepared the first comprehensive plan required under the 1986 Growth Management Act in 1988. However, future land use data were not available digitally for the 1986 timeframe and were not recreated when GIS use became prevalent. Property Appraisal Atlases in paper format were use in Brevard County until the 2000 update of the Comprehensive Plan. Therefore, there are no FLU_{t2} data. The average residential density increases from 21.2 du/ha for $FLUD_{t1}$ to 22.3 for $FLUD_{t3}$. The maximum number of units permitted in the $_{t3}$ Comprehensive Plan in one 9-ha sample area in Brevard is over 560 units. The future land use residential densities in Brevard County have not increased substantially since 1972, indicating that average densities of over du/ha at the time were ambitious. The average residential density increases from 1.3 du/ha in 1972 to 6.3 in 1999 in St. Johns County. The maximum total units permitted in one 9-ha sample

area in St. Johns County in 1999 is over 133 units. In St. Johns County residential densities were extremely low at less than 2 du/ha in 1972, increased in 1986 and again in 1999.

The 1999 average density for all sample areas in St. Johns County is 6.3 du/ha compared to Brevard County's 22.27 du/ha. Maximum densities established by the 1999 comprehensive plan are 15 du/ha in St. Johns County, compared to 70 du/ha in Brevard County. There are instances in St. Johns County such as Vilano Beach, central Anastasia Island and Summer Haven, where the number of units in 1999 exceeds the adopted future land use levels. Future land uses are established considering existing conditions, but can be established at lower levels. Vilano Beach is participating in a Florida Department of Community Affairs waterfront redevelopment program and has reconsidered development levels. Also, the use of the mid-range of the proposed densities in this research underestimates to total potential units.

Impervious Area (IMP) and Percent Impervious Area (PIM)

The impervious area (IMP) is the total number of hectares that are impervious in each 9-ha sample area. The total impervious area (IMP) is divided by the available area for development to derive the percentage impervious area (PIM). Similar to the total units (UN) and density (UH), to percentage impervious area (PIM) is affected by the amount of the sample area available for development. The average number of impervious hectares increases from 1.4 in 1972 to 2.5 in 1997 for the 138 9-ha sample areas in Brevard County increasing by 0.8 ha and 0.4 ha in the first and second time periods. The PIM increased from 21.6 percent to 39.6 percent and the increase was more rapid between 1972 and 1986. There were 9-ha sample areas containing no impervious area and others experienced a decrease in impervious hectares. Decreased impervious hectare values are consistent with the redevelopment at higher dwelling units densities, such as redevelopment of a dwelling unit with a reduced floor area ratio from the addition of another floor to the structure. This increases the total units without impacting the original building footprint.

Table 5-5. Descriptive statistics, density (UH), and future land use density (FLUD)

	Count	Mean	Standard Deviation	Min.	Max.	Kolmogorov-Smirnov	0.05	Normality
Units per Hectare (Brevard County)								
UH_{t1}	138	3.2	5.1	0.0	36.5	0.2603	0.075	Reject
UH_{t2}	138	4.3	5.5	0.0	36.5	0.2098	0.075	Reject
UH_{t3}	138	5.0	5.8	0.0	36.5	0.1889	0.075	Reject
UH_{t2-1}	138	1.1	2.4	-1.5	20.7	0.2412	0.075	Reject
UH_{t3-2}	138	0.6	1.5	-4.0	10.0	0.2390	0.075	Reject
UH_{t3-1}	138	1.8	3.3	-3.4	30.7	0.2041	0.075	Reject
Future Land Use (Brevard County)								
$FLUD_{t1}$	124	21.2	11.9	3.0	30.0	0.3994	0.079	Reject
$FLUD_{t3}$	125	22.3	22.0	0.0	70.4	0.2007	0.079	Reject
Units per Hectare (St. Johns County)								
UH_{t1}	138	1.4	1.8	0.0	8.2	0.1983	0.076	Reject
UH_{t2}	138	2.2	2.4	0.0	12.8	0.1749	0.075	Reject
UH_{t3}	138	3.5	3.2	0.0	20.9	0.1291	0.075	Reject
UH_{t2-1}	138	0.8	1.4	-1.2	7.4	0.1907	0.075	Reject
UH_{t3-2}	138	1.3	2.3	-7.3	11.3	0.2027	0.075	Reject
UH_{t3-1}	138	2.1	2.8	-3.2	15.4	0.1552	0.075	Reject
Future Land Use (St. Johns County)								
$FLUD_{t1}$	137	1.3	1.2	0.0	4.1	0.1720	0.075	Reject
$FLUD_{t2}$	138	2.3	1.8	0.0	9.1	0.0860	0.075	Reject
$FLUD_{t3}$	138	6.3	3.00	0.0	15.0	0.1987	0.075	Reject
Units per Hectare (St. Johns County, Monument 1 to 121)								
UH_{t1}	79	1.4	1.7	0.0	7.7	0.2275	0.099	Reject
UH_{t2}	83	2.1	2.2	0.0	7.9	0.2020	0.097	Reject
UH_{t3}	83	3.5	2.9	0.0	11.3	0.1375	0.097	Reject
UH_{t2-1}	83	0.8	1.1	-0.5	5.1	0.2330	0.097	Reject
UH_{t3-2}	83	1.4	2.6	-7.3	11.3	0.2123	0.097	Reject
UH_{t3-1}	83	2.2	2.7	-3.2	11.3	0.1694	0.097	Reject
Future Land Use (St. Johns County, Monument 1 to 121)								
$FLUD_{t1}$	83	1.4	1.2	0.0	3.4	0.2116	0.097	Reject
$FLUD_{t2}$	83	2.0	1.4	0.0	6. 9	0.1083	0.097	Reject
$FLUD_{t3}$	83	6.9	2.6	0.3	15.0	0.2465	0.097	Reject
Units per Hectare (St. Johns County, Monument 140 to 195)								
UH_{t1}	45	1.7	1.9	0.0	8.2	0.1806	0.131	Reject
UH_{t2}	44	2.7	2.8	0.0	12.8	0.1442	0.132	Reject
UH_{t3}	44	3.7	3.9	0.0	20.9	0.1873	0.132	Reject
UH_{t2-1}	44	1.0	1.8	-1.2	7.4	0.1493	0.132	Reject
UH_{t3-2}	44	1.0	1.7	-1.1	8.1	0.2182	0.132	Reject
UH_{t3-1}	44	2.1	3.1	-1.2	15.4	0.1839	0.132	Reject
Future Land Use (St. Johns County, Monument 140 to 195)								
$FLUD_{t1}$	43	1.6	1.3	0.0	4.1	0.2162	0.134	Reject
$FLUD_{t2}$	44	3.2	2.1	0.0	9.1	0.1223	0.132	Accept
$FLUD_{t3}$	44	6.3	3.0	0.0	14.8	0.1986	0.132	Reject

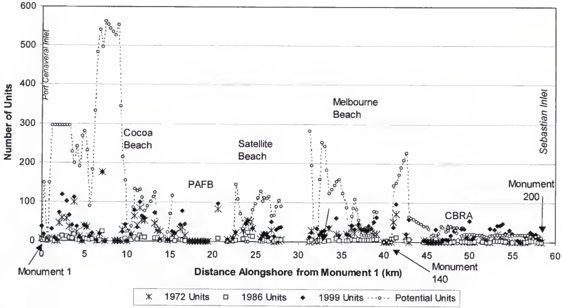

Figure 5-5. Brevard County total units, 1972-1997, with potential units (UN_{t1}, UN_{t2}, UN_{t3}, FLU_{t3})

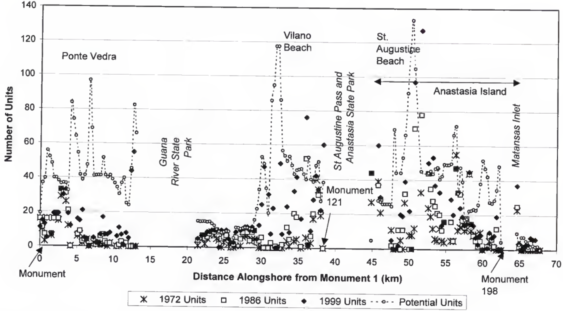

Figure 5-6. St. Johns County total units, 1972 to 1999, with potential units (UN_{t1}, UN_{t2}, UN_{t3}, FLU_{t3})

The average number of impervious hectares increases from a 1972 value of 0.2 to a 1999 value of 1.1 ha for the 138 9-ha sample areas in St. Johns County. The percentage impervious area increases over the 30-year period to a maximum of 18.3 percent in 1999. The increase in the percent impervious area from 1972 to 1999 for the 138 9-ha samples was 14.4 percent. Similar to Brevard County there are sample areas with no impervious area and decreasing amounts of impervious area over time that result from redevelopment and changes in building type.

Table 5-6. Descriptive statistics, percentage of impervious area (PIM)

	Count	Mean	Standard Deviation	Min.	Max.*	Kolmogorov-Smirnov	0.05	Normality
Percentage Impervious (Brevard County)								
PIM_{t1}	138	21.6	24.4	0.0	88.9	0.1809	0.075	Reject
PIM_{t2}	138	34.6	29.8	0.0	100.0	0.1418	0.075	Reject
PIM_{t3}	138	39.6	30.3	0.0	100.0	0.1362	0.075	Reject
Percentage Impervious (St. Johns County)								
PIM_{t1}	134	4.0	6.1	0.0	36.1	0.2457	0.076	Reject
PIM_{t2}	138	11.3	14.8	0.0	92.8	0.2163	0.075	Reject
PIM_{t3}	138	18.3	21.1	0.0	100.0	0.1854	0.075	Reject
Percentage Impervious (St. Johns County, monument 1 to 121)								
PIM_{t1}	79	3.9	5.4	0.0	27.8	0.2249	0.099	Reject
PIM_{t2}	83	8.2	10.1	0.0	41.0	0.1957	0.097	Reject
PIM_{t3}	83	12.5	11.9	0.0	56.5	0.1352	0.097	Reject
Percentage Impervious (St. Johns County, monument 141 to 195)								
PIM_{t1}	44	5.1	7.5	0.0	36.1	0.2378	0.132	Reject
PIM_{t2}	44	19.1	20.2	0.0	92.8	0.1490	0.132	Reject
PIM_{t3}	44	32.6	28.9	0.0	100.0	0.1295	0.132	Accept

* The maximum impervious area was adjusted in areas where the total exceeded 100%

Commercial (C) and Commercial Future Land Use (FLUC) Variables

The average hectares of commercial property in the sample areas in Brevard County increased from 1.0 ha in 1972 to 2.0 in 1997. There were sample areas without commercial development, and with a reduction in the number of commercial hectares. Redevelopment of commercial areas must meet Water Management District stormwater permit requirements that necessitate increased pervious area that could be an explanation of decreases in commercial area. The average hectares of commercial property in St. Johns County increased from 0.1 ha 1972 to 0.7 in 1997. The increase of 0.3 ha during each period is consistent, showing a steady rate of

commercial development countywide. In northern St. Johns County commercial hectares increases were greater from 1972 to 1986. On Anastasia Island the commercial development has been consistent, and the average commercial hectares for the sample areas for monuments 141 to 195 is higher than in northern St. Johns County. By 1999 the 44 sample areas on Anastasia Island had an average of 1.7 ha of commercial development.

Brevard County has more coastal commercial development than St. Johns County although there are areas of St. Johns County, such as St. Augustine Beach (monuments 141 to 150), where commercial development levels approach those of coastal Brevard County. Large hotel complexes and grocery stores with extensive impervious parking areas have existed in the Cocoa Beach area of Brevard County since the 1970's due to the influence of NASA, the Cape Canaveral complex and associated industries, and Patrick Air Force Base. The proposed 2010 commercial future land use in Brevard County is higher at 0.7 ha than the 0.2 ha average in St. Johns County. Not only is Brevard County more intensely developed currently, but also that the future land use intentions are for increased intensity of commercial development.

The commercial future land use designations adopted in 1989 and for 2015 show that the average area anticipated for commercial development in St. Johns County decreased from 0.4 to 0.2 ha. In northern St. Johns County (monuments 1 to 121) the commercial future land use plans show a decrease in the average and maximum hectares for commercial development. This is an indicator that the 1989 future land use designation may have been overly ambitious, and that the distance to access and lack of infrastructure and services in the form of potable water, central sewer and public safety functions that limit potential development, were recognized subsequently. In northern St. Johns County the Ponte Vedra area has developed and expanded since 1972. The influence of the Jacksonville metro area has continued to drive consistent increases in impervious area, densities and projected future land use. On Anastasia Island much of the intense condominium expansion and development occurred since 1986 and the first large grocery store was constructed in St. Augustine Beach in 2001. The maximum value for all the 9-ha sample

areas increased from 4.1 ha to 5.6 ha on Anastasia Island from 1986 to 1999. The future land use commercial designation trends in St. Johns County show a decrease in the average number of hectares with a commercial future land use, but an increase in the maximum hectares. This is an indicator of planning for more highly concentrated commercial development.

Hypotheses Testing, Bivariate Statistical Analysis

Row-wise Spearman Rank correlations were performed for both St. Johns and Brevard County (Appendix H). The variable evaluations are shown in relation to the hypothesis that each relationship supports.

Beach Width Index (BW)

The Beach Width Index (BW) variable, a measure of the distance form NGVD to the monument shows no relationship with the dependent variables in the individual time periods ($_{t1}$, $_{t2}$ and $_{t3}$) as proposed in Hypothesis 1a in Brevard County. The change in beach width from 1972 to 1986 has a positive relationship between the changes in the number of units (UN), unit density (UH), impervious area (IMP) and percentage impervious (PIM) in each of the dynamic time periods (Hypothesis 2a) (Table 5-7).

Table 5-7. Beach width change 1972 to 1986 and development variables in Brevard County

Development Variables	Beach Width Change, 1972 to 1986 (BW_{t2-1})		
	1972-1986 ($_{t2-1}$)	1986-1997 ($_{t3-2}$)	1972-1997 ($_{t3-1}$)
Units (UN)	0.205	0.248	0.306
Density (UH)	0.178	0.239	0.289
Impervious Hectares (IMP)	0.279	0.292	0.326
% Impervious (PIM)	0.216	0.282	0.259

95% confidence interval

This indicates that areas with higher intensities of development show a functional relationship with areas where beach width is accreting. It appears that the dynamic beach width change from 1972 to 1986 influences the units, units per available hectare, impervious area and hectares of commercial property in later time periods (Hypothesis 3). The impervious area measures (IMP and PIM) are highest where the total beach width change (BW_{tot}) was the highest (Hypothesis 2a). During each time period sample areas with higher total change had the highest

impervious area. The BW_{tot} variable is an absolute value so it does not distinguish between accretion and erosion. A large value for the total beach width change must be considered in conjunction with the net change (BW_{t3-1}) and beach width factor (BW_f), which is not supportable in bivariate analyses.

In St. Johns County, there are a higher number of the Beach Width (BW) test statistics at 0.05 significance, and the patterns are similar to Brevard County (Appendix H). It should be noted that the interpretation of these data should be made with caution. In St. Johns County the analyses produced a spurious result for BW_{t3} (beach width in 1999) and IMP_{t1} (impervious area in 1972). It is unlikely that the 1972 impervious area is a function of beach width in 1999 and is an example of temporal antecedence. This is noted in the following tables by the designation NA. This is an example of potential feedback between independent and dependent variables that provides potential for further research. The dependent variables in the discrete time periods show more interaction with the beach width than in Brevard County (Hypothesis 1a). For example, a positive value for the UN_{t2}, IMP_{t2}, PIM_{t2} and C_{t2} with BW_{t2} indicates that in 1986 higher numbers of units, impervious area and hectares of commercial development in each 9-ha sample area occur where the beach is widest in 1986 (Table 5-8).

Table 5-8. Beach width and impervious area in St. Johns County

Impervious Area	Beach Width (BW)			
(IMP)	1972 ($_{t1}$)	1986 ($_{t2}$)	1999 ($_{t2}$)	1972-1999 ($_{t3-1}$)
1972	0.183	0.334	0.400	0.425
1986	NA	0.460	0.512	0.411
1999	NA	NA	0.476	0.397

95% confidence interval, NA=temporal antecedence,

Similar to Brevard County, the future land use and beach width also have positive associations, indicating that the plans for higher densities were made for areas where the beach width is widest (Table 5-9). The relationship between beach width and future land use is more pronounced for Anastasia Island, when those data are considered without the rest of St. Johns County (Table 5-10). The BW variables show a consistent negative relationship between the

distance and direction to access (DACC). This indicates that areas with wider beaches are closer to the access points to the coast.

Table 5-9. Beach width and future land use in St. Johns County

Future Land Use	Beach Width (BW)			
Density (FLUD)	1972 ($_{t1}$)	1986 ($_{t2}$)	1999 ($_{t3}$)	1972-1999 ($_{t3-1}$)
1972	0.437	0.171	-	-
1999	0.340	0.374	0.317	0.342

95% confidence interval, - denotes no significance

Table 5-10. Beach width and future land use in St. Johns County (monuments 141 to 198)

Future Land Use	Beach Width (BW)		
(FLUD)	1972	1986	1999
1972	0.468	NA	NA
1999	0.541	0.730	0.637

95% confidence interval, NA=temporal antecedence,

The Beach Width Factor (BW_f) has positive relationships with the discrete time frames for units (UN), impervious area (IMP, PIM) and hectares of commercial activities (C) supporting Hypothesis 2a. BW_f has a value of between 1 and –1. Values closest to 0 indicate dynamic areas where the net change is smaller than the total change. An area can be defined as dynamic if the measure, such as beach width, has varied over time. If the net change over time is small, the original and final shoreline positions are close to each other. Therefore, a low beach width factor indicates a dynamic area. Negative values for BW_f are influenced by the negative net change because the total change is an absolute, and indicates a net reduction in beach width, or erosion. A positive relationship between BW_f and the dependent variables indicates that more intense development occurs where the beach width factor is higher and positive, indicating accretion. Using the Spearman Rank analyses in St. Johns County the BW_f indicates that during the study period decisions concerning development of the coastline have been made by appropriately assigning higher densities and intensities of use where the beach was stable or experiencing accretion. The total units in adopted in land use plans also shows that future planning will occur in areas that are more suitable (Hypothesis 2b).

Table 5-11. Beach width factor and human variables in St. Johns

Year	Human Development Variables			
	UN (n=138)	IMP (n=138)	PIM (n=134)	FLU (n=138)
1972	0.3999	0.4125	0.2280	NA
1986	0.2750	0.3996	0.2026	0.5510
1999	0.1892	0.3531	-	0.2433

95% confidence interval

Maximum Dune Height (DH)

The actual geomorphology or dune height in each time period (DH_{t1}, DH_{t2}, DH_{t2}) has a negative relationship with development variables in Brevard County (Tables 5-12 and 5-13). For example, higher numbers of actual and future units were associated with smaller dunes. This does not support Hypothesis 1a, which would anticipate a positive relationship between maximum dune height and impervious area, or higher dunes being an indicator of an area that is suitable for more intense development. Hypothesis 2a also proposes that future land uses would be more intense in areas with higher dunes but the relationship is negative.

Table 5-12. Dune height and impervious area in Brevard County

Impervious Area (IMP)	Maximum Dune Height (DH)		
	1972	1986	1997
1972	-0.607	NA	NA
1986	-0.620	-0.644	NA
1997	-0.603	-0.642	-0.627

95% confidence interval, NA=temporal antecedence,

Table 5-13. Dune height and future land use density in Brevard County

Future Land Use	Dune Height (DH)		
	1972	1986	1997
1972 ($FLUD_{t1}$)	-0.7220	NA	NA
1997 (FLU_{t3})	-0.5742	-0.5603	-0.5792
1997 ($FLUD_{t3}$)	-0.6357	-0.6210	-0.6499
1997 ($FLUC_{t3}$)	-0.4402	-0.3710	-0.3848

95% confidence interval, NA=temporal antecedence,

In Brevard County the maximum dune height is higher to the south of the county where densities are lower. The relationship between dune height and impervious area is one that would be expected of a shoreline that has been developed since the beginning of the study period. Where there are large impervious areas, sediment cannot be stored inland in dunes for coastal protection during storm events. In the event of high wave activity, the dunes seaward of the

impervious areas cannot act to absorb energy and the sediment may be carried seaward of the dune face. There is also a positive relationship between the change (1986 to 1997) in the number of density of units (UN_{t3-2}, UH_{t3-2}) and the actual geomorphology of the dune height at the discrete time periods. Areas where the maximum dune height is higher are also areas where subsequent increases in the number and intensity of units are larger (Hypothesis 3).

Table 5-14. Dune height and human variable change (1986 to 1997) in Brevard County

Human Variables (1986 to 1997)	Maximum Dune Height (DH) 1972	1986	1997
Total Units (UN)	0.3021	0.2246	0.2806
Units Density (UH)	0.2942	0.2179	0.2731

95% confidence interval

When the entire coastline of St. Johns County is considered the data do not show significant relationships between the maximum dune height and the dependent variables. There are no significant temporal relationships by time period with dune height and units, density, impervious variables, commercial development of adopted future land uses. Although the dynamic changes in dune height on Anastasia Island show some positive relationships with the number of units and units per hectare, these data are inconclusive because the pattern does not prevail for each time period (Appendix H).

Monument to Maximum Dune Height (MDH)

The changes in the distance from the monument to maximum dune height (MDH) between time periods are a measure of the geomorphic stability of the dunes in relation to a stationary point, the monument. In Brevard County the actual distance from the monument to maximum height has a negative relationship with the impervious area and adopted future land use densities during each discrete time period (Tables 5-15, 5-16). Therefore, the lower the distance between the monument and the maximum dune height, the higher the impervious area and densities.

This is counter to what was hypothesized in Hypotheses 1a and 1b, where a positive value for the distance to the maximum height was considered an indicator of a wide dune field and an area more appropriate for development.

Table 5-15. Distance from the monument to maximum height and development variables in Brevard County

Impervious Area Variables	Monument to maximum dune height (MDH) 1972 (MDH_{t1})	1986 (MDH_{t2})	1997 (MDH_{t3})
1972 (IMP_{t1})	-0.2990	NA	-
1986 (IMP_{t2})	-0.3363	-0.3075	NA
1997 (IMP_{t3})	-0.3605	-0.3002	-0.1990
1972 (PIM_{t1})	-0.2701	NA	-
1986 (PIM_{t2})	-0.2609	-0.2811	-
1997 (PIM_{t3})	-0.2792	-0.2684	-0.1035
1972 (C_{t1})	-0.3228	NA	-
1986 (C_{t2})	-0.3413	-0.3022	-
1997 (C_{t3})	-0.3534	-0.2978	-0.1875

95% confidence interval, - denotes no significance, NA=temporal antecedence,

Table 5-16. Distance from the monument to maximum dune height and future land use in Brevard County

Future Land Use	Monument to Maximum Dune Height (MDH) 1972 (MDH_{t1})	1986 (MDH_{t2})	1997 (MDH_{t3})	TOTAL (MDH_{tot})
1972 ($FLUD_{t1}$)	-0.289	NA	-	0.252
1997 (FLU_{t3})	-0.405	-0.365	-0.241	0.201
1997 ($FLUD_{t3}$)	-0.364	-0.337	-	0.259

95% confidence interval, - denotes no significance, NA=temporal antecedence,

The measure of change in MDH over time is a more appropriate indicator of the condition of the dune field, because each measure of change is independent of the original monument locations. Areas where the highest point has not migrated or a low total change (MDH_{tot}) would be appropriate for higher levels of development area under Hypothesis 2a. However, in Brevard County there is a consistent positive relationship (0.18 to 0.31) between the impervious and commercial development variables and MDH_{tot} (Table 5-17).

Table 5-17. Distance from the monument to maximum dune height and development variables in Brevard County

Monument to Maximum Dune Height (MDH_{tot})	Monument to Maximum Dune Height (MDH) IMP	PIM	C
1972 ($_{t1}$)	0.2816	0.3075	0.2741
1986 ($_{t2}$)	0.2385	0.2959	0.2355
1997 ($_{t3}$)	0.1764	0.2494	0.1820

95% confidence interval

The actual value of MDH is a function of monument placement. The goal of monument establishment was to ensure placement integrity over long time frames. The level of development at the time of monument placement and subsequent replacement will determine location. For example, placement location consistent with adjacent monuments may not be possible if the area is already developed. Monument placement would then be more seaward and in the remaining dunes, or landward adjacent to right-of-way. Subsequent to development, monument relocations have caused historical data to be rendered obsolete where the replacement was sufficiently distant from the original location (Appendix E). When the entire coastline of St. Johns County is considered, the non-parametric Spearman Rank does not show any relationships between the distance from the monument to maximum dune height and the dependent variables. Wben St. Johns County is considered by geomorphic unit, the 2015 future land use (FLU_{t3}) has a positive correlation with the time specific MDH. This is the only variable array that demonstrates the relationship anticipated by Hypothesis 1b and 2b. The density ($FLUD_{t3}$) however, is inconsistent and positive on Anastasia Island and negative in northern St. Johns County. The analyses of this variable suggest that the hypothesis is misspecified.

Maximum Height to NGVD (DHBW)

The maximum height to NGVD variable (DHBW) is a measure of beach width bounded geomorphic variables, maximum height and position of NGVD. This variable is a combination of the MDH and BW variables. In Brevard County the pattern of positive relationships between the $DHBW_{tot}$ and human variables is not consistent with the $DHBW_{f}$. As discussed earlier the use of the absolute value of $DHBW_{tot}$ as an explanatory variable without the evaluation of the direction and extent of beach width change is not possible. There are no significant relationships with $DHBW_{f}$ in Brevard County. The relationships between future land use and DHBW in Brevard County supports Hypotheses 1b and Hypothesis 3. The wider the beach in 1986, the higher the adopted total units, density and hectares of commercial development proposed for 2010.

Table 5-18. Lagged relationship between the 1986 distance from dune height to NGVD and adopted future land use variables in Brevard County

Future Land Use variables (2010)	1986 Distance from dune height to NGVD ($DHBW_{t2}$)
Units (FLU_{t3})	0.3737
Density ($FLUD_{t3}$)	0.3907
Hectares of Commercial ($FLUC_{t3}$)	0.2774

95% confidence interval

In St. Johns County, neither the entire county, nor the geomorphic divisions, demonstrate strong associations between the dependent variables and distance from dune height to NGVD variable. This is consistent with the observations for the beach width (BW) and the distance from the monument to maximum height (MDH) variables. However, northern St. Johns County experienced a uniform decrease in the distance from the maximum height to NGVD in 1999 (Appendix I). The non-parametric analysis of this variable shows that there is a negative relationship between the 1999 variable and the change in total units, unit density and adopted future land use. The change in units and densities from 1972 to 1999 and 1986 to 1999, and the proposed future land use, are inconsistent with the geomorphic condition, of width decrease and Hypotheses 1a and 2a. This relationship would be expected in the case where the decrease in distance from dune height to NGVD in 1999 was unanticipated.

Table 5-19. 1999 Distance from dune height to NGVD and change in human variables in St. Johns County

Change in Human variables	1999 Distance from dune height to NGVD ($DHBW_{t3}$)
Units (UN_{t3-2})	-0.3720
Units (UN_{t3-1})	-0.3945
Density (UH_{t3-2})	-0.4306
Density (UH_{t3-1})	-0.4148
Density ($FLUD_{t3}$)	-0.2543

95% confidence interval

Long Term Change (LT)

In Brevard County there was a positive relationship between the long-term change (LT) variable and the impervious (IMP), percent impervious area (PIM) and commercial development

(C) in the three time periods (Hypothesis 2a). This indicates that higher amounts of impervious surface and percentage of impervious surface, and commercial development occur in 9-ha sample areas with higher long-term change values, representing coastal accretion. In Brevard County the LT variable is negative only between monuments 154 to 163 (Figure 4-3 and Appendix F). The higher the long term change value the higher the potential units and densities planned for in the 1970 future land use and the most recent future land use plan supporting Hypothesis 2b. This indicates an appropriate connection between the intensity and planned future unit densities and the understanding of the long-term coastal change.

Table 5-20. Long term change, development and future land use variables, Brevard County

	Long Term Change (LT)			
Year	IMP	PIM	C	FLUD
1972 $(_{t1})$	0.3165	0.2464	0.2786	0.3172
1986 $(_{t2})$	0.3528	0.2837	0.2716	NA
1997 $(_{t3})$	0.1781	0.3165	0.3015	0.3037

95% confidence interval

In St. Johns County the number of units in the 1970's (UN_{t1}) and 1980's (UN_{t2}) show a significant positive relationship with the long-term coastal change (LT). Although similar to Brevard County, the relationships between the amount and intensity of impervious area, the indicators of more intense development being associated with a higher long-term coastal change value are less consistent. The areas of the St. Johns County coast that experience higher levels of change over time are also areas where local policy makers, through the adoption of future land use, have designated as suitable for high densities. The location of the sample area from the north (POS) showed that the long term change was more likely to be higher the further from monument 1, or the northernmost point.

Table 5-21. Long term change, development and future land use variables, St. Johns County

	Long Term Change			
Year	IMP	PIM	C	FLUD
1972 $(_{t1})$	0.2528	-	-	0.1966
1986 $(_{t2})$	0.3249	0.2631	-	0.3748
1999 $(_{t3})$	0.2786	0.2291	0.1901	0.1958

95% confidence interval

When St. Johns County is considered by geomorphic segment, dependent variables with positive relationships with accretion are the number and density of units, and the future land use and density adopted for 2015, for Anastasia Island. For Ponte Vedra to Vilano Beach there are no significant relationships between long-term change and dependent variables. The positive relationship noted between accretion, higher intensity development, and plans for greater density in both St. Johns and Brevard County suggest that the long-term coastal change is a variable that influences development patterns.

Summary of Non-parametric Results by Hypothesis

Tables 5-22 and 5-23 summarize results of the non-parametric analyses for Brevard and St. Johns County. The relationships between variables that were not predicted by the hypothesis tested are shaded. In Brevard County the maximum dune height (DH) independent variable did not exhibit relationships with the dependent variables that would be anticipated. The distance from the monument to maximum dune height to the monument in both Brevard and St. Johns County did not support the hypotheses proposed in Chapter 2. The significant results of the separate geomorphic units in St. Johns County are shown in Table 5-23 and 5-24.

Table 5-22. Summary of non-parametric results by hypothesis, Brevard County

Hypothesis	Independent Variables	Relationship	Dependent Variables
1a-Actual geomorphology and development	$DH_{t1, t2, t3}$	Negative	$IMP_{t1, t2, t3}$,
	$MDH_{t1, t2, t3}$	Negative	$(IMP, PIM, C)_{t1, t2, t3}$,
1b-Actual geomorphology and adopted future land use	$DH_{t1, t2, t3}$	Negative	$FLUD_{t1}$, FLU_{t3}, $FLUD_{t3}$, $FLUC_{t3}$
	$MDH_{t1, t2, t3}$	Negative	$FLUD_{t1}$, FLU_{t3}, $FLUD_{t3}$
2a-Dynamic geomorphology and development	BW_{t2-1}	Positive	UN_{t2-1}, UH_{t2-1}, IMP_{t2-1}, PIM_{t2-1}
	BW_{tot}	Positive	UN_{t3-1}, UH_{t3-1}, PIM_{t3-1}
	MDH_{tot}	Positive	$IMP_{t1, t2, t3}$, $PIM_{t1, t2, t3}$, $C_{t1, t2, t3}$
	LT	Positive	$IMP_{t1, t2, t3}$, $PIM_{t2, t3}$, C_{t3},
2b-Dynamic geomorphology and adopted future land use	LT	Positive	$FLUD_{t1}$, $FLUD_{t2}$, $FLUD_{t3}$
	MDH_{tot}	Positive	$FLUD_{t1}$, $FLUD_{t3}$
3-Temporal lag between the actual and dynamic geomorphology and the human variables	BW_{t2-1}	Positive	UN_{t3-2}, UH_{t3-2}, IMP_{t3-2}, PIM_{t3-2}, UN_{t3-1}, UH_{t3-1}, IMP_{t3-1}, PIM_{t3-1}
	$DH_{t1, t2, t3}$	Positive	UN_{t3-2}, UH_{t3-2}
	$DH_{t1, t2, t3}$,	Negative	$FLUD_{t1}$, $FLUD_{t3}$
	$DHBW_{t2}$	Positive	FLU_{t3}, $FLUD_{t3}$, $FLUC_{t3}$

Statistical relationship inconsistent with research hypothesis

Table 5-23. Summary of non-parametric results by hypothesis, St. Johns County

Hypothesis	Independent Variable	Relationship	Dependent Variables
1a-Actual geomorphology and development	$BW_{t1}, BW_{t2}, BW_{t3},$	Positive	$IMP_{t1}, IMP_{t2}, IMP_{t3}$
1b-Actual geomorphology and adopted future land use	$BW_{t1}, BW_{t2}, BW_{t3},$	Positive	$FLUD_{t1}, FLUD_{t3}$
2a-Dynamic geomorphology and development	$BW_{t3-1},$	Positive	$IMP_{t1}, IMP_{t2}, IMP_{t3}$
	BW_f	Positive	$UN_{t1, t2, t3}, IMP_{t1, t2, t3}, PIM_{t2, t3},$
	LT	Positive	$IMP_{t1, t2, t3}, PIM_{t1, t2, t3}, C_{t3},$
2b-Dynamic geomorphology and adopted future land use	BW_{t3-1}	Positive	$FLUD_{t1}, FLUD_{t3}$
	BW_f	Positive	FLU_{t2}, FLU_{t3}
	LT	Positive	$FLUD_{t1}, FLUD_{t2}, FLUD_{t3}$
3-Temporal lag between geomorphology and the human variables		No relationships	

Table 5-24. Summary of non-parametric results by hypothesis, Northern St. Johns County, Ponte Vedra to Vilano Beach

Hypothesis	Independent Variable	Relationship	Dependent Variables
1a-Actual geomorphology and development	$DHBW_{t3},$	Negative	$UN_{t3-2}, UN_{t3-1}, UH_{t3-2}, UH_{t3-1}$
1b-Actual geomorphology and adopted future land use	$BW_{t1}, BW_{t2}, BW_{t3},$	Positive	$FLUD_{t1}, FLUD_{t3}$
	MDH_{t2}, MDH_{t3}	Positive	FLU_{t3}
	$DHBW_{t3},$	Negative	$FLUD_{t3}$
2a-Dynamic geomorphology and development	-	-	-
2b-Dynamic geomorphology and adopted future land use	MDH_{t2-1}, MDH_{t3-1}	Positive	$FLU_{t3},$
3-Temporal lag between the actual and dynamic geomorphology and the human variables		No relationships	

Statistical relationship inconsistent with research hypothesis

Hypothesis 4, the difference between variable relationships for the two study areas, was not included in the summary tables. Hypothesis 4 is supported by the differences in significant relationships in Tables 5-22 and 5-23. The maximum dune height (DH) in Brevard County is a significant independent variable, whereas it is not significant in St. Johns County. The beach

width (BW) at the specific time periods is a significant variable in St. Johns County (Hypotheses 1a and 1b) but only the dynamic beach width variable impacts dependent variables in Brevard County (Hypothesis 2). The distance from the monument to maximum dune height (MDH) is significant in Brevard County (although not consistent with hypotheses) and the separate geomorphic units of St. Johns County, but not the entire county. The impact of a temporal lag on dependent variables (Hypothesis 3) is present Brevard County, but not in St. Johns County. Similarities between the two study areas include association between accretion and the location of higher numbers of units, density, impervious area and future land uses

Table 5-25. Summary of non-parametric results by hypothesis, Anastasia Island, St. Johns County

Hypothesis	Independent Variable	Relationship	Dependent Variables
1a-Actual geomorphology and development		No relationships	
1b-Actual geomorphology and adopted future land use	$MDH_{t2,}$ MDH_{t3}	Positive	FLU_{t3}
2a-Dynamic geomorphology and development	LT	Positive	$UN_{t2,\ t3,\ t2\text{-}1,\ t3\text{-}2,\ t3\text{-}1,}$ $UH_{t1,\ t2,\ t3,}$ $t_{2\text{-}1,\ t3\text{-}2,\ t3\text{-}1}$
	$MDH_{t2\text{-}1,}$ $MDH_{t3\text{-}1}$	Positive	FLU_{t3}, FLUDt3
2b-Dynamic geomorphology and adopted future land use	LT	Positive	$FLU_{t3,}$ $FLUD_{t3}$
3-Temporal lag between the actual and dynamic geomorphology and the human variables		No relationships	

Multivariate Statistical Analyses

Regression analyses are used to evaluate the multiple interactions of variables and to measure and model the dimensions of the impacts of variables (Appendix J). Independent variables were transformed to investigate non-linear relationships. The nominal and categorical data, such as the presence of absence of structures, renourishment, and FDEP designated areas of erosion (Clark, 1999) were used as dummy variables for analyses. Similar to the non-parametric analyses the Beach Width (BW), Dune Height (DH) variables were important. The combination of the Beach Width and Dune Height was evaluated by an interactive variable (DHBWDH). These analyses enabled the use of the categorical and ordinal variables to be evaluated for

interaction with other variables more appropriately than in the non-parametric statistical analyses. A stepwise regression of dependent variables was performed to identify potential relevant variables. Multiple regression analyses were performed for Brevard County sample areas, the entire St. Johns County data and the St. Johns County data by geomorphic area. The regression results are presented by hypothesis and a summary of the regression results is provided for each hypothesis (Appendix J).

Hypothesis 1: Local Geomorphology and Human Variables at each Time Interval

Hypothesis 1a suggests that the local geomorphology influences the human variables at that time (Conway and Nordstrom, 2003; McMichael, 1977; Miller, 1980). The total number of hectares of commercial development measured in 1999 for the entire coastline of St Johns County is the only dependent variable that has a functional relationship with actual geomorphic variables

St. Johns County, Entire Coastline-1999 Hectares of Commercial Development (C_{t3})

$C_{t3} = -7.674 - 0.022\ BW_{t3-1} - 0.347\ DH_{t3} + 0.056\ OR + 0.001(DHBW_{t3})^3$
($N=121$, $R^2=0.400$)

C_{t3} = 1999 Commercial Area (ha)
BW_{t3-1} = Change in Distance from NGVD to Maximum Dune Height 1972 to 1999 (m)
DH_{t3} = 1999 Maximum Dune Height (m)
OR = Shoreline Orientation (degrees from north)
$(DHBW_{t3})^3$= Cubed Value of 1999 Distance from NGVD to Maximum Dune Height (m)

Higher hectares of commercial activity in St. Johns County area explained by lower change in beach width from 1972 to 1999, lower dunes in 1999 and a wider beach (DHBW) in 1999. The shoreline orientation north-south (OR of 180°) rather than northwest-southeast (OR of less than 180°) is associated with higher levels of commercial development. Geomorphically higher levels of development, denoted by the hectares of commercial development, would be expected to have a positive relationship with the beach width (DHBW), or be higher where the beach was wider, and be higher where the change in beach width was lower. As was noted in the non-parametric analyses, higher intensity development occurs where dunes are smaller. Potential hypotheses for this result include the preference for development in areas with smaller dunes for

perceived improved access and visibly. Higher commercial activity may be areas long impacted by development, and so with dune fields that have been compromised over time.

Hypothesis 1b theorizes that the local geomorphology influences the land use control decision-making. This hypothesis proposes that future land use plans are developed after consideration of actual geomorphological conditions (Hails, 1977). The Brevard County adopted future land use density ($FLUD_{t1}$) is a function of the 1972 dune height, long-term change and shoreline orientation. The 1972 potential density in Brevard County, reflected in the adopted future land use, is negatively related to dune height, or lower dunes. Higher future densities were adopted in areas with low long-term change, or accretion and in the 9-ha sample areas oriented away from north. The combination of these variables explains over 60 percent of the variation in 1972 future land use densities. It may be concluded that higher densities in 1972 were planned appropriately for long-term shoreline conditions, but in areas with lower dunes. From a development perspective lower dunes are more desirable for enhanced coastal visibility. However, lack of dune protection from erosion, waves and storms make areas with lower dunes less geomorphically appropriate.

Brevard County, Entire County-1972 Future Land Use Units ($FLUD_{t1}$)
$FLUD_{t1} = -89.915 - 4.066\, DH_{t1} - 21.147\, LT + 0.821\, OR$ ($n=109$, $R^2=0.649$)

$FLUD_{t1}$ = Potential Residential Density, 1974 Comprehensive Plan (units per hectare)
DH_{t1} = 1972 Dune Height (m)
OR = Shoreline Orientation (degrees from north)

Similar to the 1972 future land use density, the 1997 total proposed units (FLU_{t3}) is a function of the dune height during that period ($_{t3}$). The future land use is also a function of the 1972 distance from the monument to maximum dune height. The 1997 potential total units in Brevard County, reflected in the 2010 adopted future land use, is associated with areas with lower dunes, similar to the 1972 density. This, in conjunction with lower distances from the monument to the maximum dune height in 1972, explains almost half of the variation in the 1997 total units.

Lower values for the distance from the monument to maximum dune height are hypothesized to be an indicator of a stable dune field. Areas with stable dune fields are more suitable for higher number of units. The 1972 variable also supports hypothesis 3, in that the FLU_{t3} is a function of the geomorphology in an earlier time period. In this case extensive coastal research was completed in 1972 (Brevard County Planning Department, 1972) that served as the base data for later recommendations.

Brevard County, Entire County-1997 Future Land Use Units (FLU_{t3})

$FLU_{t3} = 547.346 - 71.231\ DH_{t3} - 1.337 MDH_{t1}$
($n=106$, $R^2=0.479$)

FLU_{t3} = Potential Units, 1999 Comprehensive Plan
DH_{t3}= 1997 Dune Height (m)
MDH_{t1} = 1972 Distance from Monument to Maximum Height (m)

In Brevard County, a similar relationship between total number of units adopted in the 2010 future land use plan and 1997 dune height is noted in conjunction with the 1986 beach width, weighted by the road location. The negative relationship with the road weighted beach width indicates that the further the parallel access from shore, the higher the total units. If the parallel highway is further inland, the area seaward of the highway and available for development is larger. In Brevard County such areas are characterized by the development of shore-perpendicular roads and high residential densities, or commercial activities. In St. Johns County north of Vilano Beach, Highway A1A was moved inland and property was accumulated under single ownership. The resulting area is being developed as high-density (over 60 du/ha) family development called Serenata Beach.

Brevard County, Entire County-1997 Future Land Use Units (FLU_{t3})

$FLU_{t3} = 608.833 - 76.111\ DH_{t3} - 0.388\ BW_{t2}ROAD$
($n=105$, $R^2=0.517$)

FLU_{t3} = Potential Units, 1999 Comprehensive Plan
DH_{t3} = 1997 Dune Height (m)
$BW_{t2}ROAD$ = 1986 Beach Width (m) weighted by the position of the parallel access (3-<100m inland, 2-100m to 200m inland, 1->200m inland, 4 more than 1 parallel access road)

Associations between future land use and beach width occurred in St. Johns County. The density established in the 1972 future land use plan has a functional relationship with the 1972 beach width, shoreline orientation and the distance and direction to access. Higher densities were planned in areas with wider beach widths, oriented north-south and closer to access. The positive DACC value indicates the direction to the closest access is to the south. Almost half of the explanation for higher densities adopted in 1972 is a function of wider beaches, location close to access points from the barrier island and orientation.

St. Johns County, Entire Coastline-Potential Residential Density, 1979 Comprehensive Plan ($FLUD_{t1}$)
$FLUD_{t1} = 9.211 + 0.022\ BW_{t1} - 0.058\ OR + 0.085\ DACC$ ($n=124$, $R^2 = 0.498$)

$FLUD_{t1}$ = Potential Residential Density, 1979 Comprehensive Plan (units per hectare)
BW_{t1} = 1972 Distance from NGVD to Maximum Dune Height (m)
OR = Shoreline Orientation (degrees from north)
DACC = Distance and Direction from Access Point

Hypothesis 2: The Dynamic Geomorphology and Human Variables

Hypothesis 2a proposes that the dynamic geomorphology indicators influence the actual human variables and are negatively correlated to human variables (Lundberg and Handegard, 1996; McMichael, 1977; Miller, 1980). In Brevard County the long-term change (LT), orientation (OR) of the shoreline and the 1972 to 1997 absolute change in the beach width (Monument to NGVD) (BW_{tot}) were variables that influenced the percentage impervious area (PIM) in 1997.

Brevard County, Entire County-1997 Percent Impervious Area (PIM_{t3})
$PIM_{t3} = -379.003 - 0.124\ BW_{tot} - 39.611\ LT + 2.584\ OR$ ($n=110$, $R^2=0.552$)

PIM_{t3} = 1997 Percent Impervious Area (%)
BW_{tot} = Total Beach Width Change, absolute value (m)
LT = Long term Change, 1870-1999, (m)
OR = Shoreline Orientation (degrees from north)

The 1997 percentage impervious area is explained by lower total beach width change, so a less dynamic coastline, and areas where long-term change is lower. The conclusion that can be

drawn from this result is the lower the long-term change, or erosion are associated with higher impervious areas. However, as discussed earlier, Brevard County has a stable shoreline, with only the area between monument 154 and 163 experiencing long-term erosion and of ≤ 0.2 m from 1870 to 1999, so a low value of LT represents a stable shoreline. In 1997 sample areas with a high percentage of impervious area occur when the orientation is higher or orientated north-south. It would be anticipated that highly impervious sample areas would be more suitable where the total beach width change was low. Almost 60 percent of the determination of the 1997 impervious area, therefore, is a function of the orientation, in areas with stable historical shorelines and small absolute change in beach width over the study period

Hypothesis 2b proposes an adaptation of Bush and others (1999), assuming that future land use outcomes are the result of the dynamic characteristics of the physical environment. The total units in Brevard County have been demonstrated to have a negative relationship with the 1972 beach width weighted by road position. The result below shows that higher total units are associated with that variable and the long-term change, a dynamic variable in association with the structures dummy variable. Higher total units are proposed in the future land use plan where there are shoreline protection structures and accretion, and wider beaches where the road is further from the shore. An example of an area with these characteristics is Cocoa Beach. There is a sea wall present, the long-term trend is accretion, and there is a large area between Highway A1A and the shore and perpendicular streets.

Brevard County, Entire County-1997 Future Land Use Units (FLU_{t3})

$FLU_{t3} = 267.215 + 287.849$ LTSW - 0.614 BW_{t2}ROAD
($n=113$, $R^2=0.351$)

FLU_{t3} = Potential Units, Comprehensive Plan (2000)
LTSW = Long term Change, 1870-1999, (m) * Structures Dummy (1-structures present, 0-no structures)
BW_{t2} ROAD-1986 Distance from Monument to NGVD (m) weighted by the position of the parallel access (3-<100m inland, 2-100m to 200m inland, 1->200m inland, 4 more than 1 parallel access road)

On Anastasia Island, total units in the proposed future land use plan, for 2015 are a function of beach width and dune height as was the case in Brevard County. In this case the dune height variable dynamic; the change from 1972 to 1999. A positive value for orientation is also a determining factor in the total units. Higher total units planned for 2015 would be anticipated to occur where the beach width in the earlier time period was higher. The negative coefficient for change in dune height indicates that higher numbers of units are planned where the dune height change over time was low. Potential higher numbers of units are, therefore, planned in more suitable areas with wider beaches and low levels of dune change

St. Johns County South, Monument 141 to Monument 198-1999 Future Land Use Units (FLU_{t3})

$FLU_{t3} = -195.593 + 0.478\ BW_{t2} - 5.080\ DH_{t3-1} + 1.041\ OR$
($N=50$, $R^2=0.6114$)

FLU_{t3} = 1999 Potential Future Land Use, Comprehensive Plan (units)
BW_{t2} = 1986 Beach Width (m)
DH_{t3-1} = Change in Maximum Dune Height 1972 to 1999 (m)
OR = Shoreline Orientation (degrees from north)

Hypothesis 3: Temporal Lag of Geomorphic and Human Variables.

This hypothesis contemplates that geomorphology in one time period will influence human variables in later time periods (Nordstrom and Psuty, 1980; Van Der Wal, 2004). When St. Johns County is divided by geomorphic unit, over 65 percent of the variation in the density planned in 2000 for the 2015 future land use plan can be explained by a non-linear relationship with the value of the beach width in 1986, on Anastasia Island. It would be anticipated that historically wider beaches would be considered by planning officials as suitable for higher densities.

St. Johns County South, Monument 141 to Monument 198-1999 Future Land Use Density ($FLUD_{t3}$)

$FLUD_{t3} = 1.953 + 0.000001(BW_{t2})^3$
($n=53$, $R^2=0.659$)

$FLUD_{t3}$ = 1999 Future Land Use Density, Comprehensive Plan (units/hectare)
$(BW_{t2})^3$ = Cubed Value of 1986 Distance from NGVD to Maximum Dune Height (m)

Hypothesis 4: Dependent and Independent Variables in Separate Jurisdictions.

This hypothesis supposes that the explanatory power of the individual variables will be different in each part of the coastline (Byrnes et al., 1995). The Brevard County 1972 future land use density ($FLUD_{t1}$) is a function of the 1972 dune height, long term change and shoreline orientation as discussed in Hypothesis 1b. The combination of these variables explains over 60 percent of the variation in the 1972 future land use density. Higher designated density is a function of lower dunes, low long-term change and a shoreline orientation towards northwest to southeast. In contrast on Anastasia Island in St Johns County high 1972 densities ($FLUD_{t1}$) are a function of a high 1972 beach width, an opposite orientation to Brevard County (more northwest to southeast) and the proximity to access to the mainland to the south.

When the total proposed units in the future land use plan (FLU_{t3}) are considered, Brevard County total units are a function of the 1997 dune height and the 1972 distance from the monument to the maximum dune height, as discussed in Hypothesis 1b. The combination of these variables explains 48 percent of the variation in the total units proposed. Higher designated future land use units are a function of lower dunes, and a low distance to the maximum dune height. In contrast St Johns County over 60 percent of the variation in total units (FLU_{t3}) is a function of the 1986 beach width, the change in dune height from 1972 to 1999 and orientation. Higher total units occur where the beach width was wider in the earlier time period, the change in dune height is lower and the orientation is northwest to southeast.

Post Study Period Data

The study period of this research does not incorporate the 2004 hurricane season, which impacted both St. Johns and Brevard County (Appendix A). In St. Johns County, the FDEP recommends post-hurricane feasibility studies for beach restoration at Vilano Beach (monuments 110 to 117 and Summer Haven (monuments 197 to 209), and acceleration of maintenance renourishment at St Augustine Beach (monument 137 to 150) (DEP 2004b). Snell (2004) notes

that hurricane impacts were the equivalent of 50 years of coastal erosion in one season. These areas were identified as having long-term (LT) erosion (Figure 4-2, Figure 4-3) and narrow beach widths (Appendix I) in this research.

In Brevard County, maintenance renourishment is proposed to be accelerated at Cocoa Beach (monument 1 to monument 53), where dune heights (DH) were low, structures were present (SW) and beach width was narrow in this research (Appendix I). In the vicinity of Melbourne Beach (monuments 118 to 138) additional renourishment is proposed, in an area that has narrower beach width (BW, DHBW) than adjacent areas. Dune restoration is recommended for the Satellite Beach area (monuments 85 to 118) and south Brevard County (monuments 138 to 218). Although dune heights in southern Brevard County were higher than northern Brevard County, the trend was a decrease from the 1972 recorded maximum height (Appendix I). This area of Brevard County is also the only area that had long-term shoreline changes (LT) that were negative (Appendix F). Post hurricane data and recommendation (DEP 2004a, DEP 2004b) can be used to confirm that areas that were prone to erosion and dynamic change during the study period were the areas that received impacts during the 2004 hurricane season. This illustrates the relevance of the research and importance of the consideration of historical data in long-range land use planning.

CHAPTER 6
DISCUSSION AND CONCLUSIONS

Berry (in Chorley, 1973) cautioned against the "mindless use of conventional inference statistics and measures of association in geographic research, without regard for the validity of their assumptions." The potential for spurious conclusions in this research was recognized. Conclusions with temporal implications must be sequentially appropriate. For example, in St. Johns County the density of dwelling units appeared to be a function of the beach width during later time periods. Similarly, the division of St. Johns County into geomorphic unit was determined to be advantageous because the characteristics of the areas are dissimilar.

The relevance of the independent variables in relation to the dependent, or human variables, varied by jurisdiction. Similarly variables that were not important on a countywide basis were significant in St. Johns County when divided by geomorphic unit. The maximum dune height (DH) is a significant independent variable in Brevard County, but to a lesser degree in St. Johns County. The beach width (BW) at the specific time periods is a significant variable in St. Johns County (Hypotheses 1a and 1b) but only the dynamic beach width variable impacts dependent variables in Brevard County (Hypothesis 2). The distance from the monument to maximum dune height (MDH) is significant in Brevard county (although not consistent with hypotheses) and the separate geomorphic units of St. Johns County, but not the entire county. The impact of a temporal lag on dependent variables (Hypothesis 3) is present Brevard County, and St. Johns County. Similarities between the two study areas include positive associations between long-term accretion, and the location of higher numbers of units, density, impervious area and future land uses. The use of dummy variables and weighted variables were important in Brevard County, but not significant in St. Johns County. The regression analyses provided additional insight into the dimension of the interactions of variables. Similar to the non-

parametric analyses the Beach Width (BW), Dune Height (DH) and Long Term Change (LT) variables were important.

Actual Geomorphology and Human Variables

The influence of the local geomorphology on the human variables at specific time periods was noted in both jurisdictions. The dune height and distance from the monument to maximum dune height influenced the impervious area and future land use designations in Brevard County. In St. Johns County the two measures of beach width, from the monument and from the maximum dune height to NGVD, were positively correlated with the future land use designations and impervious area, as was the distance from the monument to maximum dune height (MDH) (Table 6-1). Beach width has been described as the most important independent variable from the public perception of coastal management (Foster 2002). Beach width is the most reliable indicator of coastal condition of the independent variable measurements (Foster 2002). Coastal visitors may consider dunes impediments to access or visibility, but the width of the beach is considered a positive aspect.

Table 6-1. Summary of bivariate analyses of actual geomorphology and human variables by jurisdiction

Independent Variables	Relationship	Dependent Variables
Brevard County		
$DH_{t1, t2, t3}$	Negative	$IMP_{t1, t2, t3}$, $FLUD_{t1}$, FLU_{t3}, $FLUD_{t3}$, $FLUC_{t3}$
$MDH_{t1, t2, t3}$	Negative	$(IMP, PIM, C)_{t1, t2, t3}$, $FLUD_{t1}$, FLU_{t3}, $FLUD_{t3}$
St. Johns County		
BW_{t1}, BW_{t2}, BW_{t3},	Positive	IMP_{t1}, IMP_{t2}, IMP_{t3}, $FLUD_{t1}$, $FLUD_{t3}$
St. Johns County, Ponte Vedra to Vilano Beach		
$DHBW_{t3}$,	Negative	UN_{t3-2}, UN_{t3-1}, UH_{t3-2}, UH_{t3-1} $FLUD_{t3}$
BW_{t1}, BW_{t2}, BW_{t3},	Positive	$FLUD_{t1}$, $FLUD_{t3}$
MDH_{t2}, MDH_{t3}	Positive	FLU_{t3}
Anastasia Island, St. Johns County		
MDH_{t2}, MDH_{t3}	Positive	FLU_{t3}

The total number of hectares of commercial development measured in 1999 in St Johns County an example of a dependent variable that has a functional multivariate relationship with actual geomorphic variables. This research found examples of the influence of local

geomorphology on the land use control decision-making illustrating the hypothesis that future land use plans were developed after consideration of actual geomorphological conditions.

The Brevard County adopted future land use density ($FLUD_{t1}$) is a function of the 1972 dune height, long-term change and shoreline orientation. It may be concluded that higher densities in 1972 were planned appropriately for long-term shoreline conditions, but in areas with lower dunes. Similarly, the 1997 total proposed units (FLU_{t3}) is a function of the dune height during that period ($_{t3}$). The future land use is also a function of the 1972 distance from the monument to maximum dune height. A separate 1997 total proposed units (FLU_{t3}) variation is a function of lower 1997 dune heights in conjunction with the 1986 beach width, weighted by the road location. From a development perspective lower dunes are more desirable for enhanced coastal visibility. However, lack of dune protection from erosion, waves and storms make areas with lower dunes less geomorphically appropriate. Table 6-1 shows the St. Johns County non-parametric associations between future land use and beach width. The density established in the 1972 future land use plan also has a functional relationship with multiple variables. Higher densities in 1972 were planned in areas with wider beaches, oriented north-south and closer to access.

Dynamic Geomorphology and Dependent Variables

The use of dynamic geomorphology indicators to evaluate the suitability of the coast for development was successful if simple correlations between variables were considered. However, when multivariate analyses were made, the observed numbers of units, density, impervious area, and hectares of commercial development did not have significant interactions with the geomorphology. While the dynamic geomorphology was not a determinant for the time specific human variables, it was significant in future land use plans in both Brevard and St. Johns County.

The assumption that future land use outcomes are the result of the dynamic characteristics of the physical environment is illustrated in Brevard County. The long-term change and beach width weighed by the location of roads and presence and absence of coastal protection structures.

Higher total units were proposed in the future land use plan where there are shoreline protection structures and accretion, and wider beaches in areas where the road was further from the shore.

Table 6-2. Bivariate analyses of dynamic geomorphology and human variables

Brevard County		
BW_{t2-1}	Positive	UN_{t2-1}, UH_{t2-1}, IMP_{t2-1}, PIM_{t2-1}
BW_{tot}	Positive	UN_{t3-1}, UH_{t3-1}, PIM_{t3-1}
MDH_{tot}	Positive	$IMP_{t1, t2, t3}$, $PIM_{t1, t2, t3}$, $C_{t1, t2, t3}$, $FLUD_{t1}$, $FLUD_{t3}$
LT	Positive	$IMP_{t1, t2, t3}$, $PIM_{t2, t3}$, C_{t3}, $FLUD_{t1}$, $FLUD_{t2}$, $FLUD_{t3}$
$DH_{t1, t2, t3}$	Positive	$UN_{, t3-2}$, $UH_{, t3-2}$
St. Johns County		
$BW_{t3-1,}$	Positive	IMP_{t1}, IMP_{t2}, IMP_{t3}, $FLUD_{t1}$, $FLUD_{t3}$
BW_{f}	Positive	$UN_{t1, t2, t3}$, $IMP_{t1, t2, t3}$, $PIM_{t2, t3}$, FLU_{t2}, FLU_{t3}
LT	Positive	$IMP_{t1, t2, t3}$, $PIM_{t1, t2, t3}$, C_{t3}, $FLUD_{t1}$, $FLUD_{t2}$, $FLUD_{t3}$
Northern St. Johns County, Ponte Vedra to Vilano Beach		
MDH_{t2-1}, MDH_{t3-1}	Positive	FLU_{t3},
Anastasia Island, St. Johns County		
LT	Positive	$UN_{t2, t3, t2-1, t3-2, t3-1}$, $UH_{t1, t2, t3, , t2-1, t3-2, t3-1}$, FLU_{t3}, $FLUD_{t3}$
MDH_{t2-1}, MDH_{t3-1}	Positive	FLU_{t3}, $FLUD_{t3}$

In Brevard County higher intensity of development is associated with lower maximum dune height. However the dynamic variables show that the largest changes in units and density of units have occurred in areas where the maximum dune height is largest. Therefore, when the actual geomorphology is considered, the existing pattern of development is more intense where dunes are lowest. The dynamic geomorphology variables show that the most change in units and density occurs where the maximum dune height is highest, indicating that the existing situation may not be the most suitable in terms of dune development, but increases in development intensity are occurring in more appropriate areas of Brevard County based on dune height and change in dune height over time as a measure of dune stability and development suitability. The St. Johns County total units in the proposed future land use plan, for 2015 are a function of beach width and dune height. Similar to other results, the dune height coefficient, is negative. Higher total units planned for 2015 would be anticipated to occur where the beach width in the earlier time period was higher. However, a negative coefficient for change in dune height indicates that higher numbers of units were planned where the dune height change over time was low or negative.

Influence of Geomorphic Variables on Subsequent Development

Nordstrom and others (1999) and Van Der Wal (2004) contemplate the geomorphology in one time period influencing human variables in later time periods. This was supported by both the non-parametric and parametric analyses. The non-parametric analyses showed that the lagged effect of the change in dune height impacted the number of units, density and future land use decisions in Brevard County. The distance from maximum dune height to NGVD in Brevard County in 1986 is positively correlated with the future land use and density adopted in the 2000 future land use plan. On Anastasia Island, historically wider beaches appear to have been considered by planning officials in the determination of areas suitable for that higher densities.

Variation by Location

The explanatory power of the individual variables in each part of the coastline was found to vary and support the observations of Byrnes and others (1995). The 1972 future land use ($FLUD_{t1}$) is a function of the 1972 dune height, long-term change and shoreline orientation density in Brevard County. On Anastasia Island in St Johns County, the 1972 beach width, an opposite orientation to Brevard County and the proximity to access to the mainland were significant variables. When the total proposed units in the future land use plan (FLU_{t3}) are considered, Brevard County total units are a function of the 1997 dune height and the 1972 distance from the monument to the maximum dune height. An explanation is that areas with low dunes are areas existing with high densities and impervious area, such as Cocoa Beach, and future land uses are adopted to be consistent with existing conditions. The influence of the 1972 variables is explained by use of the document titled "An open space plan to 1995 for Brevard County" (Brevard County Planning Department, 1972) as the basis of coastal data for the comprehensive plan (Kurt Easton, Brevard County planning consultant, personal communication, 2005). In contrast on Anastasia Island, the FLU_{t3} is a function of the 1986 beach width, the change in dune height from 1972 to 1999 and orientation. The negative coefficient for change in dune height indicates that higher numbers of units are planned where the dune height change over

time was low. Potential higher numbers of units are, therefore, planned in more suitable areas with wider beaches and low levels of dune change. This pattern of variables is consistent throughout all hypotheses, with the dune height influencing Brevard County dependent variables and the beach width being more important in St. Johns County.

Inaccurate Assumptions and Hypotheses Misspecifications

The statistical analyses compiled in this research produce a determination of factors that influence development. There are instances where geomorphological appropriateness may not be consistent with the development perspective. An example of this anomaly is the dune height variable. Areas more geomorphically appropriate for higher density and intensity of development would be those with higher dunes. Higher dunes provide storage areas for sediment and protection against erosion and storm damage. However, the same areas may be considered less desirable for development because high dunes may detract from access and coastal vistas. In both jurisdictions the negative relationship between human variables and dune height was noted. This conclusion is not characterized as a hypothesis misspecification, but as an unforeseen result. The results of the analyses are counterintuitive to practical geomorphological considerations for development. However, the preference for development in areas with lower dunes, while potential geomorphic folly, is a conclusion that is not unanticipated.

The distance from the monument to maximum dune height was selected as a variable to provide a measure of the impact of the dune field Allen (1991, pp. 6) used a similar measure in research at Canaveral National Seashore and stated "an accurate indicator of the true coastal 'trend' is that given by dune crestline changes." However, the explanatory power afforded by this variable is contrary to the hypotheses proposed in Chapter 2. Revised hypotheses for the distance from the monument to maximum dune height (MDH) variable are proposed. If the highest point on the profile to the monument is an indicator that the highest dune is furthest inland, a series of dunes seaward of this point would provide a buffer and sediment supply for storm activities. A low change in the position compared to the monument was hypothesized to be

important, as an indicator of a stable dune field. However, dune progradation seaward of the monument beyond the original highest point would be reflected in an increased distance from the monument over time (Figure 6-1). The conclusion of the use of the MDH variable is that the original bivariate hypothesis was misspecificed and the validity of the revised hypotheses are supported by the non-parametric results for Brevard County for MDH relationships to dependent variables.

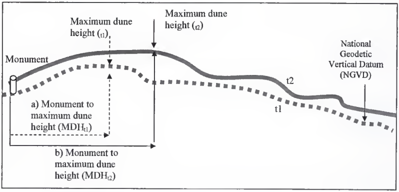

Figure 6-1. Monument to maximum dune height hypotheses revision

The two counties differ geographically and by geomorphic unit. This research illustrates the importance of consideration of coastal features by geomorphic unit, not political jurisdiction. In Brevard County the multiple coastal municipalities necessitate coordination to ensure consistency with the adjacent coastline. Geomorphic units within political boundaries should be planned for separately with consideration for specific physical characteristics. In this way planning in St. Johns County should not just overlay the entire coastal area, but should be tailored to the units north and south of the passes. Hart (2000, pp. 43) observes that "coastal management issues often influence broad geographic areas that cross political boundaries." In Florida the function of the Regional Planning Councils and State Department of Community Affairs is the ensure vertical consistency between municipal, county, regional and state planning.

Potential for Future Research

The timeframe for this research is suitable for the evaluation of developmental characteristics. The 11 to 14 year time span between records enables the research to consider the extent to which plans have been followed and development has occurred. An important consideration for future research is the overlay of geomorphic data at the same temporal scale. Data available at more frequent intervals would provide improved insight into geomorphic patterns. The long-term change variable best illustrates the use of geomorphology that is compatible with the dependent variables selected. However, this research does provide a methodology to develop physio-human modeling and evaluate the policy implications of land use planning. Modeling techniques such as GIS in conjunction with LIDAR will experience similar issues, in that the amount of data colleted spatially are even more fine-grained than this research and are difficult to compare to developmental variables which make take years to be evidenced. The quantification of human behavior in the form of coastal development patterns is made over 30 years, beyond which the impact of long-term anecdotal knowledge of coastal characteristics is difficult to quantify.

This methodology evaluating the impact of the physical environment on human variables can be applied throughout Florida. Data are available for at least three time periods for coastal counties in Florida. The potential for application of this research includes the production of a stratified classification system that could serve as a guideline for development suitability. The classification shown in Table 6-3 is an example of designation by development suitability. Areas with high long-term change, or accretion, and bigher dunes, and areas with long-term accretion and wider beaches, are most suitable for development. Areas experiencing long-term erosion, low dunes and narrow beaches are least suitable for development. A simple numeric suitability scale could be applied alongshore as a development guide. The application of the criteria in Table 6-3 to St. Johns County would result is a classification of 1 on central Anastasia Island and a value of 3 at Summer Haven, south of Matanzas Inlet.

Table 6-3. Proposed development suitability matrix

	Dune Height		Beach Width	
	High	Low	Wide	Narrow
Long-term Accretion	1	2	1	2
Long-term Erosion	2	3	2	3

1=Most appropriate for development, 2=Moderate appropriateness,
3=Least appropriate for development

In States with developed coastal management programs such as North Carolina and New Jersey coastal profile data area also available, although not at the detail or consistency of the data in Florida. The availability of LIDAR technology and data enables the profile characteristics used in this research to be determined. Historical data used in this research can be combined with LIDAR source data to expand the time series and be used as a tool for land use planners. Potentially valuable data to the extension of this research includes the use of property appraisal data at the county level. Each county is required to collect data on building type, construction, effective year built, and value, for taxation purposes. Building permit activity and type of construction data can be used to expand the human variables. Spatial presentation of residuals from the regression analyses is a technique that could be incorporated in this research to demonstrate the effectiveness of the model at each point along the coast. This technique would visually demonstrate areas unsuitable for development. The use of 9-hectare sample areas was defined as the most appropriate based on the 300m separation of data points. Further research with varied sample area sizes could test the suitability of the 9-hectare area. The potential for dummy variables can be expanded, and a potential dummy variable that accounts for development potential is vacant land. Similarly, the potential for redevelopment could be controlled with a dummy variable to evaluate the influence of newly adopted planning mechanisms such as tax increment incentives. These extensions of this research will be valuable in the evaluation of feedback loops occurring between human and physical variables. It is anticipated that the impact of the physical features (such as dune height) on human variables

(such as location of structures) is subsequently reversed with the human variable ultimately influencing the dune form in later time periods.

Final conclusions in this research would be lacking without the acknowledgment that the 2004 hurricane season was an important reminder that coastal research, even over a 30-year timeframe, is incomplete. The historical record from 1871 to 2003 shows no incidence where Florida was impacted by 4 hurricanes. Over 100 years of hurricane records does not adequately capture long-term coastal influences serves as a reminder that catastrophic and unpredictable events serve to complicate attempts at quantification and modeling the impacts of the coastal environment on human behavior.

The dynamic nature of the coastline and its role in recreation, residential and commercial development produces a dilemma. There is increasing demand for undeveloped coastal land at the same time that coastal erosion is actually decreasing the availability. Even shorelines that are "stable" are merely balanced between erosion and deposition. This balance can be rapidly altered by a change in sediment supply, sea level or the energy in the system, such as the level of storm activity. The physical characteristics of the coast are not the only aspects to experience rapid and dramatic change. In Florida each county and coastal municipality is governed by officials charged with policy making and subject to removal at the whim of the electorate. This aspect of coastal development will continue to frustrate quantification and modeling. As a consequence, coastal land use planning requires an extensive array of data, the understanding of policy implications and a long-term historical perspective. This work broadens research on the interaction of the physical environment and human occupation in the coastal zone. Determination of relationships between the physical parameters and types of development provides tools to assist coastal managers, geomorphologists, land use planners and public officials in endeavors to maximize access, while minimizing unintended impacts in coastal areas.

APPENDIX A: HURRICANES AND TROPICAL STORMS IN THE NORTHEAST FLORIDA REGION

Table A-1. Hurricanes and tropical storms that have impacted Brevard County

Date	Name	Area/Landfall/ Characteristics	Type	Source
1871 (Aug)	Unnamed	Hit east central Florida, may not have been a hurricane	H	Williams & Duedall (1997)
1876 (Sept.)	Unnamed	Traveled north along the Indian River Lagoon, or Brevard beaches (conflicting history)	O	Williams & Duedall (1997)
1880 (Aug)	Unnamed	Cocoa Beach (conflicting history, may have been further south)	H	Williams & Duedall (1997)
1885 (Aug)	Unnamed	Glanced off coast in Brevard County	O	NOAA (1987)
1921 (Oct.)	Category 3 at Tarpon Springs	Hit at Tarpon Spring on west coast and exited at Ponce de Leon Inlet	E	Jacobs (1993), Williams & Duedall (1997)
1926 (July)	Category 2	Hit south and traveled up the Indian River Lagoon, 145 km/hr winds, 73.2 cm rainfall	H	Jacobs (1993), Williams & Duedall (1997)
1928 (Aug.)	Category 2	Jupiter and traveled up the Indian River Lagoon	O	Jacobs (1993), Williams & Duedall (1997)
1960 (Sept.)	Donna	Indirect impact, exited north of Brevard County	E	Jacobs (1993), Reesman (1994)
1964 (Sept.)	Dora, Category 2	St. Augustine, North Florida, exiting, 202 km/hr winds, 72.4 cm rainfall, 3.0m. surge	H	Jacobs (1993), Williams & Duedall (1997)
1965 (Sept.)	Betsy, indirect impact	Indirect impact, 97 km/hr winds at Melbourne	O	Jacobs (1993), Reesman (1994), Williams & Duedall (1997), NOAA (1987)
1968 (Oct.)	Gladys, category	Exited north after crossing peninsular, 145 km/hr winds, 72.4 cm rainfall, 2.0m surge	E	Jacobs (1993), Reesman (1994), Williams & Duedall (1997), NOAA (1987)

Table A-1. Continued

Date	Name	Area/Landfall/ Characteristics	Type	Source
1979 (Sept.)	David, Category 2	Landfall at Melbourne, traveled north up the Indian River Lagoon and exited at New Smyrna, 145 km/hr winds, 73.0 cm rainfall	H	Jacobs (1993), Reesman (1994) Williams & Duedall (1997)
1981 (Aug.)	Dennis, Tropical Storm	Exited after passing over peninsular at Melbourne Beach	E	Williams & Duedall (1997)
1983 (Aug.)	Barry, Tropical Storm	Landfall at Melbourne Beach. Hit Texas as a hurricane after passing over peninsular	TS	Williams & Duedall (1997)
1988 (Nov.)	Keith, Tropical Storm	Landfall at Ft. Myers. Exited between Melbourne and Cape Canaveral after passing over peninsular	E	Williams & Duedall (1997)
1994 (Nov.)	Gordon, Tropical Storm	Exited after passing over peninsular at Melbourne Beach, 73 km/hr winds, tornadoes	E	Williams & Duedall (1997)
1994 (Nov.)	Gordon, Tropical Storm	Looped in Atlantic and made landfall at Cape Canaveral, 40 to 48 km/hr winds	TS	Williams & Duedall (1997),
1995 (July)	Erin, Category 1	Florida East Coast, 137 km/hr winds, 73.9 cm rainfall	H	Williams & Duedall (1997), FDEP (2000)
1996 (Aug)	Fran	Remained offshore and made landfall in North Carolina	O	FDEP (2004)
1999 (Sept)	Floyd	Remained offshore and made landfall in North Carolina	O	FDEP (2000)
1999 (Oct)	Irene	Offshore and made landfall in NE	O	FDEP (2000)
2004 (Sept)	Frances, Category 2	Landfall at Sewall's Point, FL. Stalled over southern Brevard. Max.198 km/hr winds	H	FDEP (2004a), FDEP (2004b)
2004 (Sept)	Jeanne, Category 3	Landfall at Hutchinson's Island, FL after loop in Atlantic. Tropical storm conditions in St. Johns	H	FDEP (2004a), FDEP (2004b)

Characteristics noted reflect peak winds, minimum pressure and maximum surge recorded in the east central Florida region. Data after 1945 is considered reliable. H = Hurricane, TS = Tropical Storm, E = Exiting at coast, O = Offshore.

Table A-2. Hurricanes and tropical storms that have impacted St. Johns County.

Date	Name	Area/Landfall/ Characteristics	Type	Source
1898 (Oct)	Unnamed	Fernandina Beach, 73.5 cm rainfall	H	Williams & Duedall (1997)
1921 (Oct.)	Category 3 at Tarpon Springs	Hit at Tarpon Spring on west coast and exited to ocean and Ponce de Leon Inlet	E	Jacobs (1993), Williams & Duedall (1997)
1944 (Oct.)	Unnamed	Existed at Fernandina Beach, 3.7m storm surge	E	Jacobs (1993), Reesman (1994), Williams & Duedall (1997)
1960 (Sept.)	Donna	Indirect impact, exited south of area at Daytona	E	Jacobs (1993), Reesman (1994)
1964 (Sept.)	Dora, Category 2	St. Augustine, North Florida, 202 km/hr winds, 72.4 cm rainfall, 3.7m surge	H	Jacobs (1993), Williams & Duedall (1997)
1968 (Oct.)	Gladys	Exited after crossing peninsular, 145 km/hr winds, 72.4 cm rainfall, 2.0m surge	E	Jacobs (1993), Williams & Duedall (1997), NOAA (1987)
1979 (Sept.)	David, Category 2	Traveled north up the east coast of Florida, exited at New Smyrna	O	Jacobs (1993), Reesman (1994)
1984 (Sept.)	Diana, Tropical Storm	Close to shore between Jacksonville and Daytona, 112 km/hr winds	O	Williams & Duedall (1997)
1996 (Aug)	Fran	Remained offshore and made landfall in North Carolina	O	Williams & Duedall (1997)
1999 (Sept)	Floyd	Remained offshore and made landfall in North Carolina	O	FDEP (2000)
2004 (Aug)	Charley, Category 3	Landfall at Punta Gorda, FL, exited at Daytona Beach	E	(FDEP 2004b)
2004 (Sept)	Frances, Category 2	Landfall at Sewall's Point, FL.	TS	FDEP (2004a), FDEP (2004b)
2004 (Sept)	Jeanne, Category 3	Landfall at Hutchinson's Island, FL. TS conditions in St. Johns	TS	FDEP (2004a), FDEP (2004b)

Characteristics noted reflect peak winds, minimum pressure and maximum surge recorded in the northeast Florida region. Data after 1945 is considered reliable. H = Hurricane, TS = Tropical Storm, E = Exiting at coast, O = Offshore

APPENDIX B: DEPENDENT AND INDEPENDENT VARIABLE DETAILS

Table B-1. Dependent and independent variable details

Variable Description	Name	Units	Data Sources
Monument	MON	Nominal (discrete)	Numbering System
1972 Beach Width	BW_{t1}	m	DEP converted data, http://www.dep.state.fl.us/beaches/data/his-shore.htm#ProfileData
1986 Beach Width	BW_{t2}	m	
1999 (1997) Beach Width	BW_{t3}	m	
1972 to 1986 Beach Width	BW_{t2-1}	m	Modified DEP data, derived from Annual Beach Width data
1986 to (1997)1999 Beach Width	BW_{t3-2}	m	
1972 to (1997)1999 Beach Width	BW_{t3-1}	m	
Total Beach Width Change	BW_{tot}	m	
Beach Width Factor	BW_f	Between -1 and 1	
1972 Dune Height	DH_{t1}	m	DEP converted data, http://www.dep.state.fl.us/beaches/data/his-shore.htm#ProfileData
1986 Dune Height	DH_{t2}	m	
1999 (1997)Dune Height	DH_{t3}	m	
1972 to 1986 Dune Height	DH_{t2-1}	m	Modified DEP data, derived from Annual Dune Height data
1986 to (1997)1999 Dune Height	DH_{t3-2}	m	
1972 to (1997)1999 Dune Height	DH_{t3-1}	m	
Total Dune Height Change	DH_{tot}	m	
Dune Height Factor	DH_f	-1 and 1	
1972 Monument to Dune Height	MDH_{t1}	m	DEP converted data, http://www.dep.state.fl.us/beaches/data/his-shore.htm#ProfileData
1986 Monument to Dune Height	MDH_{t2}	m	
1999 (1997) Monument to Dune Height	MDH_{t3}	m	
1972 to 1986 Monument to Dune Height	MDH_{t2-1}	m	Modified DEP data, derived from Annual Dune Height data
1986 to (1997)1999 Monument to Dune Height	MDH_{t3-2}	m	
1972 to (1997)1999 Monument to Dune Height	MDH_{t3-1}	m	
Total Monument to Dune Height Change	MDH_{tot}	m	
Monument to Dune Height Factor	MDH_f	-1 and 1	
1972 Dune Height to NGVD	$DHBW_{t1}$	m	DEP converted data, http://www.dep.state.fl.us/beaches/data/his-shore.htm#ProfileData
1986 Dune Height to NGVD	$DHBW_{t2}$	m	
1999 (1997)Dune Height to NGVD	$DHBW_{t3}$	m	
1972 to 1986 Dune Height to NGVD	$DHBW_{t2-1}$	m	Modified DEP data, derived from Annual Dune Height data
1986 to (1997)1999 Dune Height to NGVD	$DHBW_{t3-2}$	m	
1972 to 1999 Dune Height to NGVD	$DHBW_{t3-1}$	m	

Table B-1. Continued

Variable Description	Name	Units	Data Sources
Total Dune Height to NGVD Change	$DHBW_{to}$	m	Modified DEP data, derived from Annual Dune Height to NGVD data
Dune Height to NGVD Factor	$DHBW_f$	Between – 1 and 1	
Long Term Change	LT	m	http://hightide.bcs.tlh.fl.us/counties/HSSD/readme/read.me1, Olsen 1989 (Brevard) Foster et al., 2000 (St. Johns)
Shoreline Orientation	OR	In degrees from North (0)	GIS from County and Coastal Construction line (http://www.dep.state.fl.us/beaches/data/gis-data.htm#GIS_Data)
Presence of Structures	SW	Nominal	Bodge and Savage, 1989, Foster et al., 2000., St. Johns County, 2002,
DEP Erosion Designation	ER	Nominal	http://www.dep.state.fl.us/beaches/data/gis-data.htm#GIS_Data, Clarke (2002)
Renourishment	RN	Nominal	Olsen, 1989, Brevard County Comprehensive Plan, 1988, Foster et al., 2000
Dune Renourishment	RND	Nominal	Brevard County Comprehensive Plan, 1988, FDEP 2000a,
1972 Number of Units	UN_{t1}	Units	DEP Aerial Blue Line 1972, 1:1200 scale
1986 Number of Units	UN_{t2}	Units	DEP Aerial Blue Line 1986, 1:1200 scale
1999 (1997)Number of Units	UN_{t3}	Units	Brevard County DOQQ, 1997, St. Johns County DOQQ, 1999, use of Mr. Sid and X tools
1972 to 1986 Number of Units	UN_{t2-1}	Units	Derived from Annual Unit Data
1986 to (1997) 1999 Number of Units	UN_{t3-2}	Units	
1972 to 1999 Number of Units	UN_{t3-1}	Units	
1972 Units per Hectare	UH_{t1}	du/ha	Derived from Annual Unit Data and GIS determined area available
1986 Units per Hectare	UH_{t2}	du/ha	
1999(1997) Units per Hectare	UH_{t3}	du/ha	
1972 to 1986 Units per Hectare	UH_{t2-1}	du/ha	
1986 to 1999(1997) Units per Hectare	UH_{t3-2}	du/ha	
1972 to 1999 (1997)Units per Hectare	UH_{t3-1}	du/ha	
1972 Impervious Area	IMP_{t1}	ha	DEP Aerial Blue Line 1972, 1:1200 scale use of Mr. Sid and X tools
1986 Impervious Area	IMP_{t2}	ha	DEP Aerial Blue Line 1986, 1:1200 scale use of Mr. Sid and X tools
(1997) 1999 Impervious Area	IMP_{t3}	ha	Brevard County DOQQ, 1997, St. Johns County DOQQ, 1999, use of Mr. Sid and X tools
1972 to 1986 Impervious Area	IMP_{t2-1}	ha	Derived from Impervious Area Data

Table B-1. Continued

Variable Description	Name	Scale	Data Sources
1986 to 1999 (1997) Impervious Area	IMP_{t3-2}	Ha	Derived from Impervious Area Data
1972 to 1999 Impervious Area	IMP_{t3-1}	ha	
1972 Percentage Impervious	PIM_{t1}	%	Derived from Impervious Area data and GIS determined area available
1986 Percentage Impervious	PIM_{t2}	%	
1999 Percentage Impervious	PIM_{t3}	%	
1972 to 1986 Percentage Impervious	PIM_{t2-1}	%	
1986 to 1999 Percentage Impervious	PIM_{t3-2}	%	
1972 to 1999 % Impervious	PIM_{t3-1}	%	
Location of Parallel Access	ROAD	Ordinal(1 to 4)	1972 and 1986 Blue lines and 1997 (1999) DOQQ
Distance to Access	ACC	km	Use of monument position data and GIS position of access
Direction to Access	DACC	km	Use of monument position data and GIS position of access, Positive south, negative north
1972 Hectares Commercial	C_{t1}	ha	DEP Aerial Blue Line 1972, 1:1200 scale
1986 Hectares Commercial	C_{t2}	ha	DEP Aerial Blue Line 1986, 1:1200 scale
1999 Hectares Commercial	C_{t3}	ha	Brevard County DOQQ, 1997, St. Johns County DOQQ, 1999, use of Mr. Sid and X tools
1972 to 1986 Hectares Commercial	C_{t2-1}	ha	Derived from Hectares of Commercial and GIS determined area available
1986 to 1999 Hectares Commercial	C_{t3-2}	ha	
1972 to 1999 Hectares Commercial	C_{t3-1}	ha	
Future Land Use Units per Hectare	$FLUD_{t1}$	du/ha	Brevard County BOCC, 1981 (Brevard), St. Johns County, 1979 (St. Johns)
Future Land Use Units (St. Johns only)	FLU_{t2}	du/ha	St. Johns County GIS, Tim Brown (Personal Communication 2001)
Future Land Use Units per Hectare (St. Johns only)	$FLUD_{t2}$	du/ha	
Future Land Use Commercial Hectares (St. Johns only)	$FLUC_{t2}$	ha	
Number of Potential Units (beyond 2010 Brevard County, 2015 St. Johns County,)	FLU_{t3}	Units	County and City Land Use GIS data (St. Johns County, 2002). 2000 Brevard County Plan, 2001 St. Johns County Plan.
Future Land Use Residential Density	$FLUD_{t3}$	du/ha	County and City Land Use GIS data
Hectares of Commercial	$FLUC_{t3}$	hectares	County and City Land Use GIS data
Geographic Position	POS	km	Use monument Northing and Easting for distance from monument

Table B-1. Continued

Variable Description	Name	Scale	Data Sources
Transformed Variable Examples			Transformation Of All Independent Variables
Squared	$(BW_{t1})^2$	m	1972 Beach Width * 1972 Beach Width
Cubed	$(BW_{t1})^3$	m	1972 Beach Width * 1972 Beach Width * 1972 Beach Width
Log (Independent Variable)	LBW_{t1}	m	Log (1972 Beach width)

Interactive Variables Examples			Interaction Of All Independent Variables)
Dune Height * Dune Height to NGVD	$DH_{t1}DHBW_{t1}$	m	Time Specific Independent Variable * Time Specific Independent Variable (1972 Dune Height * 1972 Dune Height to NGVD)
1972 Dune Height * (1972 Dune Height to NGVD)^2	$DH_{t1}DHBW_{t1}^2$	m	Time Specific Independent Variable * (Time Specific Independent Variable)^2 1972 Dune Height * (1972 Dune Height to NGVD * 1972 Dune Height to NGVD)
(1972 Dune Height)^2 * 1972 Dune Height to NGVD	$DH_{t1}^2DHBW_{t1}$	m	(Time Specific Independent Variable)^2 * Time Specific Independent Variable (1972 Dune Height * 1972 Dune Height) * 1972 Dune Height to NGVD

Dummy Variables Examples	All Independent Variables * Dummy Variable		
Use of Erosion as Dummy	$BW_{t1}ER$	Continuous or 0	ER (1=erosion, 0=not designated) * independent variable (1972 Beach Width)
Use of Structures as Dummy	$BW_{t1}SW$	Continuous or 0	SW (1=structures present, 0=none) * independent variable (1972 Beach Width)
Use of Renourishment as Dummy	$BW_{t1}RN$	Continuous or 0	RN (1=renourishment occurred, 0=none) * independent variable (1972 Beach Width)
Use of Dune Renourishment as Dummy (Brevard County only)	$BW_{t1}RND$	Continuous or 0	RND (1=dune renourishment occurred, 0=none) * independent variable (1972 Beach Width)
Use of Position of Road as Dummy	$BW_{t1}ROAD$	Continuous or 0	ROAD (1=nearest coast >100m, 2=100-200m from sample area seaward extent, 3=0ver 200m from sample area seaward extent, 4=more than 1 parallel road in sample area) * independent variable (1972 Beach Width)

APPENDIX C: SAMPLE RAW DATA FROM THE DEPARTMENT OF ENVIRONMENTAL PROTECTION

(http://www.dep.state.fl.us/beaches/data/his-shore.htm#ProfileData)
Brevard County Department of Environmental Protection Raw Data

Countv

Date of monument establishment

Dates of Data Collection

Distance from Monument (feet)

BREVARD SEP-NOV 1972 CONTROL LINE (OK EF)
R-1
Aug-72
13-Sep-72 19-Oct-72

-200	6.61	-150	6.78	-100	6.75	-50	6.7	-13
0	8.82	12	7.79	50	7.94	87	8.39	100
122	3.25	150	2.7	200	1.29	250	-0.65	300
350	-1.68	400	-2.2	450	-2.68	500	-3.06	550
642	-2.1	741	-3.6	870	-5.8	990	-8	1134
1254	-9	1413	-9.7	1545	-11.1	1650	-12.4	1785
1950	-14.5	2160	-15.1	2280	-15.5	2397	-16	2550
2700	-17.1	2844	-17.5	2997	-18.2	3150	-18.9	

Position of Monument

R-2
Aug-72
13-Sep-72

-83	8.75	-50	9.52	0	10.32	50	9.52	100
114	10.51	124	5.11	150	3.04	200	2.34	250
300	3.39	350	3.5	400	1.77	450	0.22	500
550	-1.84	600	-2.76	650	-4.83			

Monument number

Distance from Monument (feet)

Height in relation to NGVD (feet)

APPENDIX D: USE OF AERIAL PHOTOGRAPHY AND EXCLUSION OF AREAS UNAVAILABLE FOR DEVELOPMENT

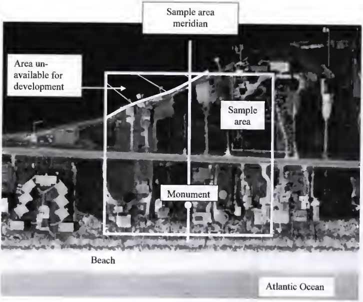

Figure D-1: Use of aerial photography and exclusion of areas unavailable for development

APPENDIX E: COUNTY MONUMENT POSITION AND PROFILE DETAILS

Table E-1. Brevard County Monument position and profile details

Monument Number	Date Set	Northing	Northing (position 2)	NS Change (in m) 1	Easting	Easting (position 2)	EW change (in m) 2
1	Jan-80	1480907.00	1480907.00	0.00	631108.50	631108.50	0.00
2	Aug-72	1480068.00			631057.50		
3	Aug-72	1479007.00			630673.00		
4	1995	Monument replaced > 3m from original					
5	Aug-72	1477177.00			630103.00		
6	Jun-85	1476239.00	1476239.00	0.00	629838.10	629838.10	0.00
7	Jan-80	1475326.00			629521.00		
8	1979	1474444.00	1474447.00	-0.91	629296.40	629282.50	4.24
9	Aug-72	1473508.00			629167.50		
10	Jan-86	Monument replaced > 3m from original					
11	Aug-72	1471632.00			628742.00		
12	Aug-72	1470689.00			628529.00		
13	Aug-72	1469729.00			628336.00		
14	Aug-72	1468813.00			628095.50		
15	Jan-80	1467834.00	1467834.00	0.00	627926.50	627926.50	0.00
16	1995	1466834.00	1466825.00	2.74	627708.50	627783.00	-22.71
17	Jan-80	1465896.00	1465901.00	-1.52	627536.30	627541.50	-1.58
18	Aug-72	1465085.00			627129.00		
19	1993	1464108.00	1464107.00	0.30	626995.50	627235.70	
20	Aug-72	1463144.00			626847.00		
21	1993	1462116.00	1462116.00	0.00	626727.50	626727.50	0.00
22	1993	1461284.00	1461283.00	0.30	626607.50	626927.80	-97.63
23	Aug-72	1460380.00			626548.70		
24	Aug-72	1459351.00			626651.50		
25	Aug-72	1458379.00			626611.50		
26	Aug-72	1457357.00			626463.00		
27	Jun-85	1456391.00	1456391.00	0.00	626367.30	625915.00	137.86
28	Jan-80	1455435.00	1455435.00	0.00	626326.10	626161.50	50.17
29	Jan-80	1454470.00	1454468.00	0.61	626265.70	626204.50	18.65
30	Aug-72	1453459.00			626190.00		
31	Aug-72	1452482.00			626068.50		
32	Jun-85	1451490.00	1451490.00	0.00	626128.50	626126.50	0.61
33	Jul-83	1450520.00	1450520.00	0.00	626098.00	626070.00	8.53
34	Aug-72	1449714.00			625814.50		
35	Jan-80	1448785.00	1448785.00	0.00	625792.50	625792.50	0.00
36	Aug-72	1447274.00			625787.50		
37	1993	1447003.00	1447013.00	-3.05	625783.91	625969.10	-56.45

Table E-1. Continued

Monument Number	Date Set	Northing	Northing (position 2)	NS Change (in m) 1	Easting	Easting (position 2)	EW change (in m) 2
38	Aug-72	1445928.00			625797.50		
39	Aug-72	1444940.00			625847.00		
40	Aug-72	1443979.00			625875.00		
41	Jan-80	1443027.00	1443027.00	0.00	625906.50	625906.50	0.00
42	Aug-72	1442029.00			625926.00		
43	Jan-80	Monument replaced > 3m from original					
44	Jan-80	Monument replaced > 3m from original					
45	1993	1439089.00	1439089.00	0.00	626001.20	626201.80	-61.14
46	Aug-72	1438130.00			626030.50		
47	Aug-72	1437135.00			626144.00		
48	Aug-72	1436195.00			626235.00		
49	1993	Monument replaced > 3m from original					
50	Jan-80	Monument replaced > 3m from original					
51	1985	1433308.00	1433307.00	0.30	626427.10	626467.00	-12.16
52	Jan-80	Monument replaced > 3m from original					
53	Jan-80	1431532.00	1431535.00	-0.91	626539.60	626564.00	-7.44
54	Jul-83	1430542.00	1430545.00	-0.91	626673.60	626690.00	-5.00
55	Jan-80	Monument replaced > 3m from original					
56	Jan-80	1428589.00	1428594.00	-1.52	626993.50	627018.50	-7.62
57	Jan-80	1427747.00	1427751.00	-1.22	627105.60	627132.40	-8.17
58	Jan-80	1426773.00	1426773.00	0.00	627256.00	627256.00	0.00
59	Jun-85	Monument replaced > 3m from original					
60	Jun-85	1424801.00	1424802.00	-0.30	627557.20	627579.00	-6.64
61	Jun-85	1423811.00	1423815.00	-1.22	627692.80	627709.00	-4.94
62	Jan-80	1422824.00	1422827.00	-0.91	627835.60	627855.00	-5.91
63	Jan-80	1421857.00	1421862.00	-1.52	627973.10	628007.00	-10.33
64	Jan-80	1420892.00	1420891.00	0.30	628132.00	628131.90	0.03
65	Jan-80	1419915.00	1419917.00	-0.61	628255.80	628271.80	-4.88
66	Aug-72	1418930.00			628402.50		
67	Jan-80	1418062.00	1418068.00	-1.83	628519.10	628532.00	-3.93
68	Jan-80	Monument replaced > 3m from original					
69	Aug-97	Position of NGVD is landward of original monument position					
70	Aug-97	Monument replaced > 3m from original					
71	Aug-97	Monument replaced > 3m from original					
72	Jan-80	Monument replaced > 3m from original					
73	Aug-97	1412305.00	1412309.00	-1.22	629154.50	629302.60	-45.14
74	Aug-97	Monument replaced > 3m from original					
75	Aug-72	1410446.00			629438.50		
76	Jan-80	Monument replaced > 3m from original					
77	Jan-80	1408603.00	1408603.00	0.00	629686.00	629686.00	0.00
78	Jan-80	1407611.00	1407617.00	-1.83	629809.40	629831.50	-6.74
79	1993	Monument replaced > 3m from original					
80	1993	Monument replaced > 3m from original					
81	Aug-97	1404749.00	1404746.00	0.91	630238.50	630270.40	-9.72
82	Jan-80	1403779.00	1403787.00	-2.44	630410.10	630439.50	-8.96

Table E-1. Continued

Monument Number	Date Set	Northing	Northing (position 2)	NS Change (in m) **1**	Easting	Easting (position 2)	EW change (in m) **2**
83	Jan-80	1402842.00	1402839.00	0.91	630592.80	630597.50	-1.43
84	Aug-72	1401866.00			630805.50		
85	Aug-72	1401148.00			630957.50		
86	1993	Monument replaced > 3m from original					
87	1993	Monument replaced > 3m from original					
88	Jan-80	1398219.00	1398229.00	-3.05	631601.70	631603.00	-0.40
89	Jan-80	1397353.00	1397355.00	-0.61	631789.10	631810.50	-6.52
90	Jan-80	1396744.00	1396742.00	0.61	631925.10	631923.00	0.64
91	Jan-80	1395879.00	1395879.00	0.00	632151.50	632151.50	0.00
92	Jan-80	1395007.00	1395007.00	0.00	632354.00	632354.00	0.00
93	Aug-72	1394034.00			632579.50		
94	Jan-80	1393061.00	1393061.00	0.00	632790.50	632790.50	0.00
95	Jan-80	1392304.00	1392299.00	1.52	632933.20	632953.00	-6.04
96	Aug-72	1391383.00			633158.50		
97	1993	1390479.00	1390479.00	0.00	633371.50	633371.50	0.00
98	Aug-72	1389503.00			633588.50		
99	1993	Monument replaced > 3m from original					
100	1993	Monument replaced > 3m from original					
101	Aug-72	1386622.00			634229.00		
102	Aug-97	Monument replaced > 3m from original					
103	Jun-85	1384696.00	1384696.00	0.00	634662.00	634662.00	0.00
104	Aug-97	Monument replaced > 3m from original					
105	1993	Monument replaced > 3m from original					
106	1993	Monument replaced > 3m from original					
107	Jan-80	1380966.00	1380972.00	-1.83	635512.80	635748.00	-71.69
108	Jul-83	1380073.00	1380073.00	0.00	635716.50	635716.50	0.00
109	Jan-80	1379165.00	1379165.00	0.00	635931.50	635931.50	0.00
110	Jan-80	Monument replaced > 3m from original					
111	Aug-72	1377232.00			636442.00		
112	Aug-97	1376261.00	1376260.00	0.30	636673.10	636673.50	-0.12
113	Jan-80	1375414.00	1375414.00	0.00	636902.00	636902.00	0.00
114	Aug-72	1374518.00			637162.00		
115	1993	Monument replaced > 3m from original					
116	Jun-85	1372683.00	1372673.00	3.05	637704.60	637602.50	31.12
117	Jan-80	Monument replaced > 3m from original					
118	1993	Monument replaced > 3m from original					
119		No Data					
120	Jun-85	1369059.00	1369058.00	0.30	638779.00	638777.80	0.37
121	Jan-80	Monument replaced > 3m from original					
122	Aug-72	1366336.00			639568.50		
123	Aug-72	1365417.00			640083.50		
124	Aug-72	1364473.00			640358.00		
125	Jun-85	Monument replaced > 3m from original					
126	Jun-85	1363536.00	1363536.00	0.00	640734.50	640734.50	0.00
127	1993	Monument replaced > 3m from original					

Table E-1. Continued

Monument Number	Date Set	Northing	Northing (position 2)	NS Change (in m) 1	Easting	Easting (position 2)	EW change (in m) 2
128	Aug-72	1361873.00			641084.60		
129	Jan-80	1360881.00	1360881.00	0.00	641479.00	641485.00	-1.83
130	Jun-85	1359937.00	1359935.00	0.61	641763.00	641753.20	2.99
131	Aug-97	1359104.00	1359096.00	2.44	642111.00	642132.90	-6.68
132	Aug-72	1358374.00			642423.50		
133	1993	1357367.00	1357367.00	0.00	642818.00	642818.00	0.00
134	Jun-85	1356417.00	1356417.00	0.00	643230.70	643230.70	0.00
135	Jun-85	1355516.00	1355516.00	0.00	643581.30	643581.30	0.00
136	1993	Monument replaced > 3m from original					
137	Jan-80	Monument replaced > 3m from original					
138	Aug-97	1352802.00	1352811.00	-2.74	644652.50	644741.60	-27.16
139	Aug-72	1351748.00			645011.00		
140	Aug-72	1351077.00			645378.00		
141	Aug-72	1350124.00			645745.50		
142	Aug-72	1349406.00			646044.00		
143	Aug-72	1348492.00			646410.90		
144	Jun-85	Monument replaced > 3m from original					
145	Aug-97	Monument replaced > 3m from original					
146	Aug-97	Monument replaced > 3m from original					
147	Jan-80	1344983.00	1344983.00	0.00	647893.40	647893.40	0.00
148	Aug-72	1344095.00			648282.50		
149	Aug-97	Monument replaced > 3m from original					
150	Aug-97	Monument replaced > 3m from original					
151	Aug-97	Monument replaced > 3m from original					
152	Aug-97	Monument replaced > 3m from original					
153	Aug-97	Monument replaced > 3m from original					
154	Aug-72	1338832.00			650508.00		
155	Aug-72	1337608.00			651052.00		
156	Aug-72	1337148.00			651274.50		
157	Jan-80	1336077.00	1336077.00	0.00	651732.00	651732.00	0.00
158	Aug-72	1335353.00			652034.40		
159	Jan-80	1334497.00	1334497.00	0.00	652399.00	652399.00	0.00
160	Aug-72	1333463.00			652850.50		
161	Aug-72	1332714.00			653298.50		
162	Aug-72	1332110.00			653470.00		
163	Aug-72	1331027.00			654042.00		
164	Aug-72	1330330.00			654410.50		
165	Aug-97	1329464.00	1329461.00	0.91	654860.00	655000.40	-42.79
166	Aug-72	1328338.00			655854.50		
167	Aug-97	Monument replaced > 3m from original					
168	Aug-97	Monument replaced > 3m from original					
169	Jun-85	1325623.00	1325623.00	0.00	656480.50	656480.50	0.00
170	Jan-80	1324727.00	1324727.00	0.00	656970.00	656967.50	0.76
171	Jan-80	1323888.00	1323884.00	1.22	657359.00	657355.50	1.07
172	Aug-72	1322966.00			657757.00		

Table E-1. Continued

Monument Number	Date Set	Northing	Northing (position 2)	NS Change (in m) 1	Easting	Easting (position 2)	EW change (in m) 2
173	Aug-72	1321996.00			658131.50		
174	Aug-72	1321094.00			658425.90		
175	Jan-80	Monument replaced > 3m from original					
176	Aug-97	Monument replaced > 3m from original					
177	Aug-72	1318478.00			659781.00		
178	Aug-97	Monument replaced > 3m from original					
179	Aug-72	1316957.00			660544.50		
180	Aug-72	1315966.00			661052.50		
181	Aug-97	Monument replaced > 3m from original					
182	Aug-72	1314224.00			661977.50		
183	Aug-72	1313400.00			662408.00		
184	Aug-72	1312458.00			662906.50		
185	Aug-72	1311555.00			663309.00		
186	Jul-83	1310668.00	1310668.00	0.00	663836.50	663836.50	0.00
187	Aug-97	1310039.00	1310048.00	-2.74	664161.00	664320.10	-48.49
188	Aug-72	1309184.00			664529.50		
189	Jul-83	1308323.00	1308323.00	0.00	665064.50	665064.50	0.00
190	Aug-97	Monument replaced > 3m from original					
191	Aug-72	1306571.00			665926.50		
192	Aug-97	1305691.00	1305690.00	0.30	666400.90	666399.50	0.43
193	Jan-86	Monument replaced > 3m from original					
194	Aug-72	1303899.00			667338.00		
195	Aug-72	1303012.00			667799.50		
196	Aug-72	1302124.00			668245.80		
197	Aug-72	1301171.00			668647.00		
198	Aug-72	1300284.00			669115.50		
199	Aug-72	1299474.00			669532.00		
200	Aug-72	1298501.00			670026.00		
201	No Data	Monument replaced > 3m from original					
202	No Data	126886.00	126992.00	-32.31	670848.50	671139.40	-88.67
203-218	No Data	Monument replaced > 3m from original					
219	Aug-72	1282426.00			687108.40		

Notes

1 Negative sign represents movement to south of original position

2 Negative sign represents movement to west of original position

Table E-2. St. Johns County Monument position and profile details

Monument Number	Date Set	Northing	Northing (position 2)	NS Change (in m) 1	Easting	Easting (position 2)	EW change (in m) 2
1	Jun-72	2151940.35			379681.86		
2	Jun-72	2150939.04			379906.64		
3	Jun-72	2149962.53			380124.53		
4	1995	2149012.72	2149014.45	-0.53	380332.33	380338.24	-1.80
5	Jun-79	2148015.11	2148016.92	-0.55	380332.33	380564.46	-70.75
6	Jun-72	2147032.27			380787.71		
7	Jun-72	2146036.28			381013.14		
8	Jun-72	2145049.30			381235.83		
9	Jun-72	2144045.63			381465.14		
10	1995	2142995.74	2142991.46	1.31	381709.32	381697.97	3.46
11	1995	2141978.43	2141979.43	-0.31	381943.82	381945.26	-0.44
12	Jun-72	2140909.86			382189.05		
13	Jun-72	2139874.45			382471.06		
14	Jan-84	2138789.89	2138790.16	-0.08	382736.89	382737.85	-0.29
15	May-84	2137737.55	2137736.88	0.20	383002.67	383001.40	0.39
16	Jul-86	Monument replaced > 3m from original					
17	Jun-72	2135718.15			383504.00		
18	Jun-72	2134730.17			383776.22		
19	Jun-72	2133735.63			384042.45		
20	Jun-72	2132738.50			384253.30		
21	Jun-72	2131727.80			384493.70		
22	Jun-72	2130724.03			384687.52		
23	1995	Monument replaced > 3m from original					
24	Jun-72	2128728.69			385169.08		
25	Jun-72	2127709.24			385409.38		
26	May-84	2126711.64	2126711.64	0.00	385651.96	385651.96	0.00
27	Jun-72	2125718.56			385904.01		
28	Jun-72	2124677.71			386095.03		
29	Jun-72	2123703.93			386352.13		
30	Jun-72	2122677.47			386526.67		
31	Jun-72	2121671.81			386789.35		
32	Jan-79	Monument replaced > 3m from original					
33	Feb-84	Monument replaced > 3m from original					
34	Jun-72	2118620.47			387441.59		
35	Jan-79	2117655.75	2117656.14	-0.12	387657.93	387656.84	0.33
36	Jun-72	2116619.01			387874.65		
37	Jun-72	2115584.45			388105.19		
38	1995	2114563.50	2114569.80	-1.92	388314.26	388316.42	-0.66
39	Jun-72	2113528.29			388543.45		

Table E-2. Continued

Monument Number	Date Set	Northing	Northing (position 2)	NS Change (in m) 1	Easting	Easting (position 2)	EW change (in m) 2
40	Jan-79	2112517.35	2112517.35	0.00	388763.10	388763.10	0.00
41	Jan-79	2111481.57	2111481.57	0.00	388976.38	388976.38	0.00
42	Jun-72	2110457.78			389178.67		
43	1995	Monument replaced > 3m from original					
44	Jun-72	2108407.28			389591.89		
45	Jun-72	2107393.56			389799.32		
46	Jun-72	2106383.68			389992.19		
47	Jan-79	2105379.92	2105379.92	0.00	390214.70	390214.70	0.00
48	Jan-79	2104374.91			390432.05		
49	Jun-72	2103364.60			390640.87		
50	Jun-72	2102343.64			390863.23		
51	Jun-72	2101309.58			391028.73		
52	Jun-72	2100261.02			391246.60		
53	Jun-72	2099279.51			391422.34		
54	Jun-72	2098258.55			391673.41		
55	Jun-72	2097243.91			391873.84		
56	Jun-72	2096230.22			392084.44		
57	Jun-72	2095150.50			392298.10		
58	Jun-72	2094155.21			392509.07		
59	Jun-72	2093124.33			392740.47		
60	Jun-72	2092077.59			392965.69		
61	Jun-72	2091036.21			393185.75		
62	Jun-72	2090014.32			393407.57		
63	Jun-72	2088967.43			393626.06		
64	Jun-72	2087935.98			393795.97		
65	Jun-72	2086874.70			394012.75		
66	Jun-72	2085847.39			394249.65		
67	Jun-72	2084801.70			394430.91		
68	Jun-72	2083775.51			394623.58		
69	Jun-72	2082754.72			394837.02		
70	Jan-79	Monument replaced > 3m from original					
71	Jun-72	2080719.18			395188.19		
72	Jun-72	2079709.52			395362.25		
73	Jun-72	2078674.75			395565.70		
74	Jun-72	2077642.82			395718.85		
75	Jun-72	2076617.39			395911.18		
76	Jun-72	2075588.83			396099.64		
77	Jun-72	2074545.24			396311.07		
78	Jan-79	2073501.24	2073501.24	0.00	396515.64	396515.64	0.00
79	Jun-72	2072415.14			396753.06		

Table E-2. Continued

Monument Number	Date Set	Northing	Northing (position 2)	NS Change (in m) 1	Easting	Easting (position 2)	EW change (in m) 2
80	Jun-72	2071417.13			396987.89		
81	Jun-72	2070331.86			397217.60		
82	Jul-86	2069333.74	2069339.25	-1.68	397410.43	397453.31	-13.07
83	Jun-72	2068287.23			397635.12		
84	1995	2067226.08	2067224.61	0.45	397885.14	397886.11	-0.30
85	Jun-72	2066207.09			398122.08		
86	1995	Monument replaced > 3m from original					
87	Jun-72	2064183.33			398585.38		
88	Jun-72	2063162.67			398808.02		
89	Jun-72	2062226.11			398999.67		
90	Jun-72	2061225.57			399238.55		
91	Jun-72	2060196.91			399430.46		
92	Jun-72	2059161.55			399642.04		
93	Jun-72	2058188.99			399877.97		
94	Jun-72	2057183.72			400067.27		
95	Jun-72	2056211.45			400261.71		
96	Jun-72	2055202.43			400525.80		
97	Jun-72	2054206.45			400768.16		
98	1995	Monument replaced > 3m from original					
99	Jun-72	2052183.11			401190.73		
100	Jun-72	2051168.29			401427.64		
101	1995	2050145.73	2050152.81	-2.16	401624.22	401645.40	-6.46
102	1995	2049184.59	2049177.14	2.27	401876.61	401869.05	2.30
103	Jun-72	2048209.66			402087.52		
104	Jan-79	2047248.24	2047248.24	0.00	402323.27	402323.27	0.00
105	Jun-72	2046282.58			402558.22		
106	Jan-79	Monument replaced > 3m from original					
107	Aug-86	2044267.32	2044264.00	1.01	403094.99	403123.40	-8.66
108	Jun-72	2043236.49			403395.76		
109	1995	Monument replaced > 3m from original					
110	Jan-79	2041170.25	2041166.09	1.27	403965.23	403919.26	14.01
111	Jun-72	2040148.68			404231.70		
112	Jan-79	Monument replaced > 3m from original					
113	Jun-72	2038183.57			404808.90		
114	Jan-79	Monument replaced > 3m from original					
115	Jun-72	2036177.22			405413.59		
116	Feb-84	2035161.69	2035161.69	0.00	405727.89	405727.90	0.00
117	Jun-72	2034104.35			406102.11		
118	Jun-72	2033084.26			406485.12		
119	Jun-72	2032061.73			406921.04		

Table E-2. Continued

Monument Number	Date Set	Northing	Northing (position 2)	NS Change (in m) 1	Easting	Easting (position 2)	EW change (in m) 2
120	Jun-72	2031034.98			407363.87		
121	Jun-72	2030032.20			407769.34		
122	1999	2028981.33			408117.83		
123	1995	Monument replaced > 3m from original					
124	Jan-79	Monument replaced > 3m from original					
'125	1995	2024401.27	2024401.27	0.00	410287.51	410287.51	0.00
'126	Jan-79	2023529.80	2023529.80	0.00	411383.60	411383.60	0.00
127	Feb-84	Monument replaced > 3m from original					
128	Jan-79	Monument replaced > 3m from original					
129	Jan-79	Monument replaced > 3m from original					
130	Jan-79	Monument replaced > 3m from original					
131	1998	Monument replaced > 3m from original					
132	Jan-79	Monument replaced > 3m from original					
133	Feb-84	Monument replaced > 3m from original					
134	1998	Monument replaced > 3m from original					
135	Feb-84	Monument replaced > 3m from original					
136	Feb-84	Monument replaced > 3m from original					
137	1998	Monument replaced > 3m from original					
'138	Jan-79	2011540.80	2011542.48	-0.51	414680.19	414685.08	-1.49
139	Feb-95	Monument replaced > 3m from original					
140	Feb-95	Monument replaced > 3m from original					
141	Jun-72	2008862.42			415279.70		
142	1995	Monument replaced > 3m from original					
143	Oct-83	Monument replaced > 3m from original					
'143A	1973	200663.24	200663.24	0.00	200663.24	200663.24	0.00
144	Oct-83	2005831.25	2005831.27	-0.01	415575.23	415575.23	0.00
145	1999	2004805.12	2004803.95	0.36	415600.61	415598.00	0.80
146	Feb-95	Monument replaced > 3m from original					
147	Jan-84	Monument replaced > 3m from original					
148	1997	Monument replaced > 3m from original					
149	1999	Monument replaced > 3m from original					
150	1999	1999839.03	1999839.25	-0.07	416059.47	416062.12	-0.81
151	Jun-72	1998834.38			416040.56		
152	Jun-72	1997849.50			416108.85		
153	Jun-72	1996847.12			416185.94		
154	Jun-72	1995858.34			416223.93		
155	Jun-72	1994860.73			416335.43		
156	Jan-79	1993857.83	1993857.83	0.00	416393.22	416393.22	0.00
157	Jan-79	Monument replaced > 3m from original					
158	Jun-72	1991867.33			416507.20		

Table E-2. Continued

Monument Number	Date Set	Northing	Northing (position 2)	NS Change (in m) 1	Easting	Easting (position 2)	EW change (in m) 2
159	Jan-79	1990823.78	1990823.78	0.00	416579.44	416579.44	0.00
160	Jun-72	1989749.24			416778.39		
161	Jan-79	1988689.50	1988689.50	0.00	413974.55	413974.55	0.00
162	Jun-72	1987775.82			417078.72		
163	Jun-72	1986781.99			417265.09		
164	Jun-72	1985789.56			417446.41		
165	Jun-72	1984793.34			417617.63		
166	Jun-72	1983804.61			417804.44		
167	Jun-72	1982808.73			417945.86		
168	Jun-72	1981851.00			418268.00		
169	Jun-72	1980858.53			418453.51		
170	Jul-86		Monument replaced > 3m from original				
171	Jan-79		Monument replaced > 3m from original				
172	Jan-79	1977923.69	1977931.19	-2.29	419315.38	419251.88	19.36
173	Jun-72	1976910.16			419509.44		
174	1995	1975927.49	1975931.16	-1.12	419793.17	419803.38	-3.11
175	Jun-72	1974965.70			420102.20		
176	1999	1973988.30	1974000.45	-3.70	420376.60	420407.61	-9.45
177	Jun-72	1973078.40			420692.30		
178	Jun-72	1972123.39			421018.97		
179	Jun-72	1971139.74			421300.45		
180	Jun-72	1970226.93			421608.59		
181	Jan-79	1969334.30	1969337.86	-1.09	421895.30	421889.19	1.86
182	Jun-72	1968374.37			422230.74		
183	Jan-79	1967420.91	1967420.91	0.00	422535.53	422535.53	0.00
184	Nov-83	1966439.00	1966439.00	0.00	422844.00	422844.00	0.00
185	Jan-79	1965547.24	1965544.46	0.85	423198.28	423204.53	-1.90
186	Jun-72	1964574.38			423544.90		
187	1974	1963637.48	1963636.85	0.19	423888.11	423885.89	0.68
188	Jul-86	1962632.15	1962632.15	0.00	424227.44	424227.44	0.00
189	Jun-72	1961665.78			424608.67		
190	Jun-72	1960710.72			424958.42		
191	Jun-72	1959786.44			425371.24		
192	Jun-72	1958858.98			425784.40		
193	Jun-72	1957935.42			426216.81		
194	Jan-79	1956981.54	1956975.04	1.98	426662.17	426670.39	-2.51
195	Jun-72	1956065.25			427111.16		
196	Jan-79		Monument replaced > 3m from original				
197	1995		Monument replaced > 3m from original				
197A	Jan-79	1951647.69	1951647.69	0.00	428227.75	428227.75	

Table E-2. Continued

Monument Number	Date Set	Northing	Northing (position 2)	NS Change (in m) 1	Easting	Easting (position 2)	EW change (in m) 2
198	Jul-86	Monument replaced > 3m from original					
199	Jun-72	1950313.29			428953.79		
200	1995	1949330.77	1949336.57	-1.77	429181.89	429186.98	-1.55
201	Jun-72	1948349.60			429461.86		
202	Jun-72	1947377.53			429714.76		
203	Jun-72	1946403.51			430046.87		
204	1995	1945422.29	1945414.55	2.36	430345.73	430320.48	7.69
205	Jul-86	1944435.88	1944443.13	-2.21	430640.02	430628.51	3.51
206	Jun-72	1943461.44			430951.19		
207	Jun-72	1942475.66			431257.00		
208	Jun-72	1941525.40			431632.38		
209	Jun-72	1940544.78			431959.23		

Notes

1 Negative sign represents movement to south of original position

2 Negative sign represents movement to west of original position

* No data in 1972, 1986 position used as original

APPENDIX F: BREVARD COUNTY LONG TERM CHANGE DETERMINATION

Table F-1. Brevard County long term change determination

Monument	End Point (m)	Rate Averaging (Olsen 1989) (m)	Difference (m)	Average of Olsen and End Point (m)	(LT) Adjacent Average (m)
1	1.23	1.52	0.29	1.38	1.36
2	1.16	1.52	0.36	1.34	1.10
3	0.88	0.30	-0.57	0.59	0.97
4					
5	0.86	0.61	-0.25	0.73	0.85
6	1.03	0.91	-0.12	0.97	0.95
7	1.21	1.07	-0.15	1.14	1.14
8	1.40	1.22	-0.18	1.31	1.13
9	0.49	1.37	0.88	0.93	1.12
10					
11	0.30	1.68	1.37	0.99	0.99
12	0.28	1.68	1.39	0.98	0.97
13	0.19	1.68	1.48	0.94	0.96
14	0.41	1.52	1.11	0.97	0.94
15	0.30	1.52	1.23	0.91	0.93
16	0.44	1.37	0.94	0.90	0.90
17	0.40	1.37	0.97	0.89	1.08
18	1.54	1.37	-0.17	1.46	1.24
19	1.51	1.22	-0.29	1.36	1.36
20	1.48	1.07	-0.41	1.27	1.29
21	1.41	1.07	-0.35	1.24	1.26
22					
23	1.27	0.91	-0.36	1.09	1.03
24	1.17	0.76	-0.41	0.97	0.93
25	0.67	0.76	0.09	0.72	0.86
26	1.16	0.61	-0.55	0.89	0.80
27					
28					
29					
30	1.11	0.46	-0.65	0.78	0.74
31	1.08	0.30	-0.78	0.69	0.71
32	0.98	0.30	-0.68	0.64	0.63
33	0.79	0.30	-0.48	0.55	0.43
34	0.07	0.15	0.08	0.11	0.35

Table F-1. Continued

Monument	End Point (m)	Rate Averaging (Olsen 1989) (m)	Difference (m)	Average of Olsen and End Point (m)	(LT) Adjacent Average (m)
36	0.72	0.15	-0.57	0.44	0.42
37					
38	0.61	0.15	-0.46	0.38	0.39
39	0.63	0.15	-0.47	0.39	0.38
40	0.61	0.15	-0.45	0.38	0.38
41	0.59	0.15	-0.44	0.37	0.38
42	0.64	0.15	-0.49	0.40	0.39
43					
44					
45					
46	0.52	0.15	-0.36	0.33	0.33
47	0.51	0.15	-0.35	0.33	0.34
48	0.57	0.15	-0.42	0.36	0.35
49					
50					
51	0.46	0.15	-0.30	0.30	0.30
52					
53	0.36	0.15	-0.21	0.26	0.25
54	0.34	0.15	-0.18	0.24	0.25
55					
56	0.28	0.15	-0.13	0.22	0.21
57	0.24	0.15	-0.09	0.20	0.20
58	0.23	0.15	-0.08	0.19	0.19
59					
60	0.19	0.15	-0.04	0.17	0.13
61	0.03	0.15	0.12	0.09	0.18
62	0.42	0.15	-0.27	0.29	0.20
63	0.28	0.15	-0.13	0.22	0.23
64	0.23	0.15	-0.08	0.19	0.20
65	0.25	0.15	-0.10	0.20	0.21
66	0.33	0.15	-0.17	0.24	0.22
67	0.30	0.15	-0.15	0.23	0.23
68					
69					
70					
71	0.10	0.30	0.21	0.20	0.20
72					
73					
74					
75	0.05	0.30	0.25	0.18	0.18
76					
77	0.08	0.30	0.22	0.19	0.18

Table F-1. Continued

Monument	End Point (m)	Rate Averaging (Olsen 1989) (m)	Difference (m)	Average of Olsen and End Point (m)	(LT) Adjacent Average (m)
79					
80					
81	0.14	0.15	0.01	0.15	0.13
82	0.07	0.15	0.08	0.11	0.10
83	0.06	0.00	-0.06	0.03	0.06
84	0.06	0.00	-0.06	0.03	0.02
85	-0.03	0.00	0.03	-0.01	0.01
86					
87					
88	0.20	0.00	-0.20	0.10	0.10
89	0.19	0.00	-0.19	0.10	0.10
90	0.21	0.00	-0.21	0.11	0.09
91	0.12	0.00	-0.12	0.06	0.08
92	0.13	0.00	-0.13	0.06	0.07
93	0.15	0.00	-0.15	0.07	0.06
94	0.05	0.00	-0.05	0.03	0.05
95	0.11	0.00	-0.11	0.06	0.04
96	0.05	0.00	-0.05	0.03	0.03
97	-0.01	0.00	0.01	0.00	0.01
98					
99					
100					
101					
102					
103					
104					
105					
106					
107					
108	-0.03	0.00	0.03	-0.01	0.00
109	0.03	0.00	-0.03	0.02	0.00
110					
111	-0.02	0.00	0.02	-0.01	-0.02
112	-0.05	0.00	0.05	-0.02	0.00
113	0.06	0.00	-0.06	0.03	0.02
114	-0.04	0.15	0.20	0.05	0.04
115					
116	0.09	0.15	0.07	0.12	0.12
117					
118					
119					
120	0.09	0.15	0.06	0.12	0.12
121					
122	0.18	0.15	-0.03	0.17	0.16

Table F-1. Continued

Monument	End Point (m)	Rate Averaging (Olsen 1989) (m)	Difference (m)	Average of Olsen and End Point (m)	(LT) Adjacent Average (m)
123	0.14	0.15	0.01	0.15	0.16
124	0.14				0.14
125					
126	0.26	0.30	0.04	0.28	0.28
127					
128	0.13	0.30	0.17	0.22	0.22
129					
130	0.11	0.15	0.05	0.13	0.14
131	0.13	0.15	0.02	0.14	0.12
132	0.05	0.15	0.11	0.10	0.11
133	0.05	0.15	0.10	0.10	0.11
134	0.08	0.15	0.07	0.12	0.11
135	0.06	0.15	0.09	0.11	0.11
136					
137					
138	0.12	0.15	0.03	0.14	0.13
139	0.09	0.15	0.06	0.12	0.12
140	0.08	0.15	0.07	0.12	0.12
141	0.08	0.15	0.08	0.11	0.11
142	0.04	0.15	0.11	0.10	0.09
143	-0.01	0.15	0.16	0.07	0.08
144					
145					
146					
147	0.12	0.30	0.19	0.21	0.21
148					
149					
150					
151					
152					
153					
154	-0.05	0.00	0.05	-0.02	-0.03
155	-0.07	0.00	0.07	-0.03	-0.04
156	-0.11	0.00	0.11	-0.05	-0.05
157	-0.14	0.00	0.14	-0.07	-0.07
158	-0.14	0.00	0.14	-0.07	-0.08
159	-0.20	0.00	0.20	-0.10	-0.08
160	-0.15	0.00	0.15	-0.07	-0.07
161	-0.12				-0.13
162	-0.12				-0.07
163	0.02				-0.03
164	0.01				0.03
165	0.06				0.04
166					

Table F-1. Continued

Monument	End Point (m)	Rate Averaging (Olsen 1989) (m)	Difference (m)	Average of Olsen and End Point (m)	(LT) Adjacent Average (m)
167					
168					
169	-0.03				
170	0.16	0.15	0.00	0.15	0.14
171	0.10	0.15	0.06	0.12	0.17
172	0.16	0.30	0.15	0.23	0.18
173	0.08	0.30	0.23	0.19	0.20
174	0.08	0.30	0.23	0.19	0.19
175					
176					
177	0.15	0.46	0.30	0.31	0.31
178					
179	0.24	0.61	0.37	0.42	0.38
180	0.07	0.61	0.54	0.34	0.38
181					
182	0.24	0.46	0.22	0.35	0.34
183	0.21	0.46	0.24	0.34	0.32
184	0.10	0.46	0.36	0.28	0.27
185	0.09	0.30	0.22	0.20	0.23
186	0.11	0.30	0.20	0.21	0.20
187	0.10	0.30	0.20	0.20	0.21
188	0.16	0.30	0.14	0.23	0.22
189	0.15	0.30	0.16	0.23	0.23
190					
191	0.13	0.30	0.18	0.22	0.24
192	0.24	0.30	0.07	0.27	0.24
193					
194	0.20	0.30	0.10	0.25	0.24
195	0.14	0.30	0.16	0.22	0.23
196	0.14	0.30	0.16	0.22	0.23
197	0.17	0.30	0.14	0.24	0.24
198	0.24	0.30	0.06	0.27	0.26
199	0.22	0.30	0.09	0.26	0.26
200	0.17	0.30	0.14	0.24	0.25
		Average difference between Olsen and End Point		0.03	

APPENDIX G: DESCRIPTIVE STATISTICS, BREVARD AND ST. JOHNS COUNTY

Table G-1. Descriptive statistics, dependent and independent variables, Brevard County

	Count	Mean	Standard Deviation	Min.	Max.	Kolmogorov-Smirnov	0.05	Normality
Monument to Maximum Dune Height								
MDH_{t1}	146	49.0	28.1	0	111.9	0.1037	0.073	Reject
MDH_{t2}	142	47.1	29.5	0	152.4	0.0728	0.074	Accept
MDH_{t3}	142	52.4	30.1	0	152.4	0.0803	0.074	Reject
MDH_{t2-1}	139	-2.1	21.3	-71.0	82.3	0.1626	0.075	Reject
MDH_{t3-2}	136	5.2	23.2	-57.9	110.3	0.1997	0.076	Reject
MDH_{t3-1}	139	3.22	27.5	-69.2	129.2	0.1952	0.075	Reject
MDH_{tot}	133	26.7	29.6	0	137.2	0.1912	0.076	Reject
MDH_{f}	133	-0.01	0.8	-1	1	0.1368	0.076	Reject
Maximum Dune Height to NGVD								
$DHBW_{t1}$	148	49.2	27.0	4.1	149.9	0.1920	0.072	Reject
$DHBW_{t2}$	141	57.2	23.6	24.3	157.9	0.1966	0.074	Reject
$DHBW_{t3}$	140	49.9	21.7	19.5	199.9	0.1910	0.075	Reject
$DHBW_{t2-1}$	141	8.4	24.8	-76.1	82.4	0.1258	0.074	Reject
$DHBW_{t3-2}$	135	-7.3	24.6	-108.2	72.9	0.1550	0.076	Reject
$DHBW_{t3-1}$	141	1.6	28.9	-115.2	155.3	0.1803	0.074	Reject
$DHBW_{tot}$	137	34.3	32.7	0	155.3	0.1766	0.075	Reject
$DHBW_{f}$	135	0.2	0.7	-1	1	0.1031	0.076	Reject
Number of Units								
UN_{t1}	138	17.7	24.2	0	176	0.2249	0.075	Reject
UN_{t2}	138	24.0	27.6	0	176	0.1854	0.075	Reject
UN_{t3}	138	28.1	28.6	0	176	0.1555	0.075	Reject
UN_{t2-1}	138	6.2	10.9	-10	58	0.2265	0.075	Reject
UN_{t3-2}	138	4.1	9.4	-23	50	0.2291	0.075	Reject
UN_{t3-1}	138	10.4	14.3	-22	58	0.1867	0.075	Reject
Hectares of Impervious								
IMP_{t1}	138	1.4	1.6	0	8	0.1858	0.075	Reject
IMP_{t2}	138	2.2	2.0	0	8	0.1534	0.075	Reject
IMP_{t3}	138	2.5	2.0	0	8	0.1253	0.075	Reject
IMP_{t2-1}	138	0.8	1.0	-0.7	5.0	0.2024	0.075	Reject
IMP_{t3-2}	138	0.3	0.7	-0.6	5.0	0.2470	0.075	Reject
IMP_{t3-1}	138	1.1	1.2	-0.6	5.7	0.1576	0.075	Reject
Hectares of Commercial								
C_{t1}	138	1.0	1.6	0	8	0.2457	0.075	Reject
C_{t2}	138	1.7	1.9	0	8	0.1775	0.075	Reject
C_{t3}	138	1.9	2.0	0	8	0.1558	0.075	Reject
C_{t2-1}	138	0.6	1.0	-0.7	5	0.2668	0.075	Reject
C_{t3-2}	138	0.3	0.7	-0.6	5	0.3100	0.075	Reject
C_{t3-1}	138	0.9	1.2	-0.7	5.8	0.1792	0.075	Reject

Table G-1. Continued

	Count	Mean	Standard Deviation	Min.	Max.	Kolmogorov-Smirnov	0.05	Normality
Future Land Use								
FLU_{t3}	125	110.7	131.035	0	562.31	0.1912	0.079	Reject
$FLUC_{t3}$	125	0.7	1.326	0	6.4	0.3504	0.079	Reject

Table G-2. Descriptive statistics, dependent and independent variables, St. Johns County

	Count	Mean	Standard Deviation	Min.	Max.	Kolmogorov-Smirnov	0.05	Normality
Monument to Maximum Dune Height								
MDH_{t1}	116	6.8	7.9	0.0	45.7	0.1856	0.082	Reject
MDH_{t2}	117	11.2	12.9	0.0	53.0	0.1867	0.081	Reject
MDH_{t3}	116	13.1	15.3	0.0	72.2	0.1951	0.082	Reject
MDH_{t2-1}	119	4.4	14.5	-45.7	53.0	0.2190	0.081	Reject
MDH_{t3-2}	119	1.7	11.4	-23.8	72.2	0.2646	0.081	Reject
MDH_{tot}	120	6.1	16.9	-36.6	72.2	0.2288	0.080	Reject
MDH_{tot}	120	14.3	16.1	0.0	72.2	0.1789	0.080	Reject
MDH_{f}	120	0.1	0.8	-1.0	1.0	0.1822	0.080	Reject
Maximum Dune Height to NGVD								
$DHBW_{t1}$	166	74.9	20.1	20.1	135.8	0.1557	0.068	Reject
$DHBW_{t2}$	168	88.2	31.2	19.5	190.6	0.1439	0.068	Reject
$DHBW_{t3}$	166	77.1	31.4	22.4	170.9	0.1870	0.068	Reject
$DHBW_{t2-1}$	169	14.5	23.8	-76.5	139.5	0.1246	0.068	Reject
$DHBW_{t3-2}$	169	-12.0	16.9	-64.2	53.2	0.0747	0.068	Reject
$DHBW_{t3-1}$	169	2.6	25.4	-76.5	131.2	0.1806	0.068	Reject
$DHBW_{tot}$	169	35.3	26.7	1.3	147.8	0.1574	0.068	Reject
$DHBW_{f}$	169	-0.1	0.6	-1.0	1.0	0.0759	0.068	Reject
Number of Units								
UN_{t1}	138	7.2	10.2	0	55	0.2318	0.075	Reject
UN_{t2}	138	11.1	14.2	0	78	0.2111	0.075	Reject
UN_{t3}	138	17.8	19.6	0	127	0.1796	0.075	Reject
UN_{t2-1}	138	3.9	8.7	-9	58	0.2614	0.075	Reject
UN_{t3-2}	138	6.7	12.0	-11	60	0.2616	0.075	Reject
UN_{t3-1}	138	10.6	16.5	-11	94	0.2287	0.075	Reject
Hectares of Impervious								
IMP_{t1}	138	0.2	0.4	0.0	2.1	0.2955	0.075	Reject
IMP_{t2}	138	0.6	1.0	0.0	5.0	0.2500	0.075	Reject
IMP_{t3}	138	1.1	1.4	0.0	6.9	0.2228	0.075	Reject
IMP_{t2-1}	138	0.4	0.8	-0.4	5.0	0.2819	0.075	Reject
IMP_{t3-2}	138	0.4	1.0	-0.4	6.8	0.2732	0.075	Reject
IMP_{t3-1}	138	0.8	1.3	-0.1	6.7	0.2381	0.075	Reject

Table G-2.

	Count	Mean	Standard Deviation	Min.	Max.	Kolmogorov-Smirnov	0.05	Normality
Hectares of Commercial								
C_{t1}	138	0.1	0.3	0.0	1.8	0.4799	0.075	Reject
C_{t2}	136	0.4	0.9	0.0	5.0	0.3545	0.076	Reject
C_{t3}	134	0.7	1.4	0.0	6.8	0.3355	0.076	Reject
C_{t2-1}	138	0.3	0.8	-0.4	5.0	0.3646	0.075	Reject
C_{t3-2}	138	0.3	1.0	-0.8	6.8	0.3686	0.075	Reject
C_{t3-1}	138	0.6	1.3	-0.3	6.8	0.3353	0.075	Reject
Future Land Use								
FLU_{t2}	138	13.1	13.7	0.0	76.2	0.1615	0.075	Reject
$FLUC_{t2}$	138	0.4	0.9	0.0	4.1	0.3092	0.075	Reject
FLU_{t3}	138	36.8	26.1	0.0	133.0	0.1294	0.075	Reject
$FLUC_{t3}$	138	0.2	0.7	0.0	5.6	0.5016	0.075	Reject

Table G-3. Descriptive statistics, dependent and independent variables, Ponte Vedra to St. Augustine Pass (Monument 1 to 122) St. Johns County

	Count	Mean	Standard Deviation	Min.	Max.	Kolmogorov-Smirnov	0.05	Normality
Monument to Maximum Dune Height								
MDH_{t1}	66	5.7	6.9	0.0	30.5	0.1881	0.108	Reject
MDH_{t2}	67	8.2	6.9	0.0	27.7	0.1169	0.108	Reject
MDH_{t3}	66	8.1	7.00	0.0	27.7	0.1668	0.108	Reject
MDH_{t2-1}	69	2.5	8.5	-22.0	27.7	0.1955	0.106	Reject
MDH_{t3-2}	69	-0.2	6.3	-20.8	20.4	0.2149	0.106	Reject
MDH_{t3-1}	70	2.3	9.2	-22.0	26.8	0.1759	0.105	Reject
MDH_{tot}	70	9.3	9.3	0.3	36.6	0.2129	0.105	Reject
MDH_{f}	70	0.01	0.8	-1.0	1.0	0.1885	0.105	Reject
Maximum Dune Height to NGVD								
$DHBW_{t1}$	111	68.4	8.3	41.7	85.7	0.0913	0.084	Reject
$DHBW_{t2}$	110	77.7	11.7	45.4	111.7	0.0587	0.084	Accept
$DHBW_{t3}$	110	63.8	12.8	35.7	118.9	0.0697	0.084	Accept
$DHBW_{t2-1}$	110	9.3	12.1	-17.1	43.8	0.0668	0.084	Accept
$DHBW_{t3-2}$	110	-13.8	14.3	-64.2	45.4	0.1189	0.084	Reject
$DHBW_{t3-1}$	110	-4.5	11.7	-45.6	35.1	0.1052	0.084	Reject
$DHBW_{tot}$	110	28.9	18.0	1.3	104.5	0.1291	0.084	Reject
$DHBW_{f}$	110	-0.2	0.5	-1.00	1.0	0.1179	0.084	Reject

Table G-3. Continued

	Count	Mean	Standard Deviation	Min.	Max.	Kolmogorov-Smirnov	0.05	Normality
Number of Units								
UN_{t1}	83	5.6	8.3	0.0	40.0	0.2513	0.097	Reject
UN_{t2}	83	8.3	9.9	0.0	52.0	0.2184	0.097	Reject
UN_{t3}	83	15.5	14.9	0.	76.0	0.2196	0.097	Reject
UN_{t2-1}	83	2.7	5.6	-3.0	46.0	0.2781	0.097	Reject
UN_{t3-2}	83	7.2	13.1	-11.0	60.0	0.2964	0.097	Reject
UN_{t3-1}	83	9.9	14.7	-11.0	70.0	0.2754	0.097	Reject
Hectares of Impervious								
IMP_{t1}	83	0.2	0.4	0.0	1.9	0.3274	0.097	Reject
IMP_{t2}	83	0.4	0.7	0.0	3.3	0.2839	0.097	Reject
IMP_{t3}	83	0.4	0.7	0.0	3.3	0.2338	0.097	Reject
IMP_{t2-1}	83	0.2	0.5	-0.02	3.3	0.3264	0.097	Reject
IMP_{t3-2}	83	0.2	0.4	-0.4	2.2	0.3026	0.097	Reject
IMP_{t3-1}	83	0.5	0.8	-0.1	4.3	0.2587	0.097	Reject
DACC	81	2.2	8.8	-13.0	16.9	0.0678	0.098	Accept
Hectares of Commercial								
C_{t1}	83	0.1	0.3	0.0	1.8	0.5070	0.097	Reject
C_{t2}	82	0.2	0.7	0.0	3.3	0.4190	0.097	Reject
C_{t3}	80	0.3	0.8	0.0	4.3	0.3687	0.098	Reject
C_{t2-1}	82	0.2	0.5	-0.3	3.3	0.4302	0.097	Reject
C_{t3-2}	80	0.1	0.4	-0.8	2.1	0.4009	0.098	Reject
C_{t3-1}	80	0.3	0.7	-0.3	4.3	0.3765	0.098	Reject
Future Land Use								
FLU_{t2}	83	9.4	8.1	0.0	51.9	0.1330	0.097	Reject
$FLUC_{t2}$	83	0.6	1.1	0.0	4.1	0.3195	0.097	Reject
FLU_{t3}	83	38.0	24.6	0.0	117.0	0.1270	0.097	Reject
$FLUC_{t3}$	83	0.1	0.5	0.0	2.0	0.3195	0.097	Reject

Table G-4. Descriptive statistics, dependent and independent variables, Anastasia Island (Monuments 141-195), St. Johns County

	Count	Mean	Standard Deviation	Min.	Max.	Kolmogorov-Smirnov	0.05	Normality
Monument to Maximum Dune Height								
MDH_{t1}	39	6.7	8.9	0.0	45.7	0.2105	0.140	Reject
MDH_{t2}	39	16.4	19.2	0.0	53.0	0.2443	0.140	Reject
MDH_{t3}	39	23.0	21.3	0.0	72.2	0.1840	0.140	Reject
MDH_{t2-1}	39	9.8	21.6	-45.7	53.0	0.2428	0.140	Reject
MDH_{t3-2}	39	6.6	17.0	-23.8	72.2	0.3018	0.140	Reject
MDH_{t3-1}	39	16.4	23.4	-36.6	72.2	0.2024	0.140	Reject
MDH_{tot}	39	24.7	21.9	0.0	72.2	0.1713	0.140	Reject
MDH_{f}	39	0.3	0.8	-1.0	1.0	0.2215	0.140	Reject
Maximum Dune Height to NGVD								
$DHBW_{t1}$	44	99.5	18.5	47.5	135.8	0.1014	0.132	Accept
$DHBW_{t2}$	47	125.2	29.6	40.2	190.6	0.1161	0.128	Accept
$DHBW_{t3}$	47	116.0	28.8	23.1	170.9	0.1439	0.128	Reject
$DHBW_{t2-1}$	48	31.3	34.9	-76.5	139.5	0.1243	0.127	Accept
$DHBW_{t3-2}$	48	-8.9	21.9	-60.1	53.2	0.1036	0.127	Accept
$DHBW_{t3-1}$	48	22.4	36.8	-76.5	131.2	0.1678	0.127	Reject
$DHBW_{tot}$	48	53.9	35.1	3.1	147.8	0.1183	0.127	Accept
$DHBW_{f}$	48	0.4	0.6	-1.0	1.0	0.1583	0.127	Reject
Number of Units and Hectares of Impervious								
UN_{t1}	44	11.5	12.5	0.0	55.0	0.2333	0.132	Reject
UN_{t2}	44	18.3	18.9	0.0	78.0	0.1434	0.132	Reject
UN_{t3}	44	24.9	25.9	0.0	127.0	0.1664	0.132	Reject
UN_{t2-1}	44	6.8	13.0	-9.0	58.0	0.1394	0.132	Reject
UN_{t3-2}	44	6.6	11.0	-9.0	49.0	0.2199	0.132	Reject
UN_{t3-1}	44	13.5	20.7	-8.0	94.0	0.1582	0.132	Reject
IMP_{t1}	45	0.3	0.5	0.0	2.1	0.2599	0.131	Reject
IMP_{t2}	44	1.2	1.2	0.0	5.0	0.1502	0.132	Reject
IMP_{t3}	44	2.1	1.9	0.0	6.9	0.1439	0.132	Reject
IMP_{t2-1}	44	0.9	1.2	-0.4	5.0	0.2452	0.132	Reject
IMP_{t3-2}	44	0.9	1.6	-0.3	6.8	0.2687	0.132	Reject
IMP_{t3-1}	44	1.8	1.8	0.0	6.7	0.1643	0.132	Reject
Hectares of Commercial								
C_{t1}	44	0.1	0.4	0.0	1.5	0.4495	0.132	Reject
C_{t2}	43	0.9	1.2	0.0	5.0	0.2146	0.134	Reject
C_{t3}	43	1.7	1.9	0.0	6.8	0.2020	0.134	Reject
C_{t2-1}	44	0.7	1.2	-0.4	5.0	0.2358	0.132	Reject
C_{t3-2}	44	0.8	1.6	-0.3	6.6	0.3035	0.132	Reject
C_{t3-1}	44	1.5	1.9	-0.02	6.6	0.2139	0.132	Reject
Future Land Use								
FLU_{t2}	44	22.7	17.8	0.0	76.2	0.2007	0.132	Reject
$FLUC_{t2}$	44	0.2	0.4	0.0	1.6	0.2752	0.132	Reject
FLU_{t3}	44	42.7	26.3	0.0	133.0	0.1884	0.132	Reject
$FLUC_{t3}$	44	0.4	1.1	0.0	5.6	0.4836	0.132	Reject

APPENDIX H: NON-PARAMETRIC STATISTICS (SPEARMAN RANK) ROW WISE CORRELATIONS, BREVARD AND ST. JOHNS COUNTY.

Table H-1. Brevard County Spearman Rank analyses, Beach Width (BW) and dependent variables at 0.05 significance

	BW_{t1}	BW_{t2}	BW_{t3}	BW_{t2-1}	BW_{t3-2}	BW_{t3-1}	BW_{tot}	BW_tLT	
UN_{t1}	-	-	-	-	-	-	0.1750	-	-
UN_{t2}	-	-	-	-	-	-		-	-
UN_{t3}	-	-	-	-	-	-	-	-	-
UN_{t2-1}	-	-	-	0.2022	-	-	-	-	-
UN_{t3-2}	-	-	-	0.2478	-	-	-	-	-
UN_{t3-1}	-	-	-	0.3057	-0.2666	-	-	-	-
UH_{t1}	-	-	-	-	-	-	-	-	-
UH_{t2}	-	-	-	-	-	-	-	-	-
UH_{t3}	-	-	-	-	-	-	-	-	-
UH_{t2-1}	-	-	-	0.1779	-0.1800	-	-	-	-
UH_{t3-2}	-	-	-	0.2394	-	-	-	-	-
UH_{t3-1}	-	-	-	0.2789	-0.2615	-	-	-	-
IMP_{t1}	-	-	-	-	0.2047	-	0.3699	-	0.3165
IMP_{t2}	-	-	-	-	-	-	0.3656	-	0.3528
IMP_{t3}	-	-	-	-	-	0.1922	0.3566	-	0.1781
IMP_{t2-1}	-	-	-	0.2794	-	0.1860	-	-	0.2188
IMP_{t3-2}	-	-	-	0.2916	-	0.2350	-	-	0.2437
IMP_{t3-1}	-	-	-	0.3258	-	0.2660	-	-	0.3106
PIM_{t1}	-	-	-	-	0.1894	-	0.3528	-	0.2464
PIM_{t2}	-	-	-	-	-	-	0.2998	-	0.2837
PIM_{t3}	-	-	-	-	-	-	0.2902	-	0.3165
PIM_{t2-1}	-	-	-	0.2163	-	-	-	-	-
PIM_{t3-2}	-	-	-	0.2825	-	0.2285	-	-	0.2111
PIM_{t3-1}	-	-	-	0.2593	-	-	-	-	-
ACC	-	-	-	-0.1885	-	-	-0.3701	-	-0.1878
DACC	-0.2265	-	-0.2078	-	-	-	0.3234	-	-
POS	0.1858	-	-	-	-	-0.2736	-0.5891	-	-0.5590

Table H-1. Continued

	BW_{t1}	BW_{t2}	BW_{t3}	BW_{t2-1}	BW_{t3-2}	BW_{t3-1}	BW_{tot}	BW_f	LT
C_{t1}	-	-	-	-	0.1896	-	0.3454	-	0.2786
C_{t2}	-	-	-	-	-	-	0.3489	-	0.2716
C_{t3}	-	-	-	-	-	-	0.3364	-	0.3015
C_{t2-1}	-	-	-	0.2000	-	-	-	-	-
C_{t3-2}	-	-	-	0.1980	-	0.2078	-	-	-
C_{t3-1}	-	-	-	0.2537	-	0.2249	0.2019	-	0.2107
$FLUD_{t1}$	-	-	-	-	-	-	0.4639	-	0.3172
FLU_{t3}	-0.1836	-	-	-	-	0.2363	0.4046	-	0.3299
$FLUD_{t3}$	-	-	-	-	-	-	0.3804	-	0.3037
$FLUC_{t3}$	-	-	-	-	-	-	-	-	-

Table H-2. Brevard County Spearman Rank analyses, Dune Height (DH)) and dependent variables at 0.05 significance

	DH_{t1}	DH_{t2}	DH_{t3}	DH_{t2-1}	DH_{t3-2}	DH_{t3-1}	DH_{tot}	DH_{f}	OR
UN_{t1}	-0.2679	-0.3054	-0.2439	-	-	-	-	-	0.4059
UN_{t2}	-0.2093	-0.2424	-0.2043	-	-	-	-	-	0.3400
UN_{t3}	-	-	-	-	-	-	-	-	0.2172
UN_{t2-1}	-	-	-	-	-0.1933	-	-0.2402	-	-
UN_{t3-2}	0.3021	0.2246	0.2806	-	-	-0.2244	-	-	-0.2843
UN_{t3-1}	0.1907	-	-	-	-	-0.2360	-0.2730	-	-
UH_{t1}	-0.2826	-0.3096	-0.2544	-	-	-	-	-	0.4138
UH_{t2}	-0.2282	-0.2351	-0.2037	-	-	-	-	-	0.3162
UH_{t3}	-	-0.1818	-	-	-	-	-	-	0.2173
UH_{t2-1}	-	-	-	-	-0.1888	-	-0.2168	-	-
UH_{t3-2}	0.2942	0.2179	0.2731	-	-	-0.2149	-0.1852	-	-0.2804
UH_{t3-1}	-	-	-	-	-	-0.1839	-0.2699	-	-
IMP_{t1}	-0.6065	-0.6680	-0.6234	-	-	-	-	-	0.7398
IMP_{t2}	-0.6203	-0.6436	-0.6405	-	-	-	-	-	0.7294
IMP_{t3}	-0.6034	-0.6418	-0.6270	-	-	-	-	-	0.7246
IMP_{t2-1}	-0.2892	-0.2250	-0.2411	-	-	-	-	-	0.3706
IMP_{t3-2}	-	-	-	-	-	-	-0.2638	-	-
IMP_{t3-1}	-0.2833	-0.2250	-0.2570	-	-	-	-0.2013	-	0.3976
PIM_{t1}	-0.6100	-0.6510	-0.6208	-	0.2246	-	-	-	0.7148
PIM_{t2}	-0.6420	-0.6309	-0.6420	-	-	-	0.1851	-	0.7273
PIM_{t3}	-0.6361	-0.6332	-0.6406	-	-	-	-	-	0.7396
PIM_{t2-1}	-0.3141	-0.2327	-0.2501	-	-	-	-	-	0.3821
PIM_{t3-2}	-	-	-	-	-	-	-0.2667	-	-
PIM_{t3-1}	-0.3242	-0.2406	-0.2826	-	-	-	-	-	0.4228
ACC	0.6154	0.5899	0.5779	-	-	-0.2790	-	-0.1830	-0.7404
DACC	-0.6218	-0.5705	-0.6018	-	-	0.1824	0.1966	0.1459	0.7366
POS	0.8744	0.8440	0.8710	-	-	-0.2310	-0.2308	-	0.4059
C_{t1}	-0.5759	-0.6040	-0.5972	-	0.2231	-	0.1891	-	0.3400
C_{t2}	-0.5751	-0.5787	-0.5733	-	0.1878	-	0.2129	-	0.2172
C_{t3}	-0.5709	-0.5876	-0.5759	-	-	-	-	-	-
C_{t2-1}	-0.2751	-0.2427	-0.2363	0.1045	-	-	-	-	-0.2843
C_{t3-2}	-0.1277	-0.1120	-0.1485	-	-	-	-	-	-
C_{t3-1}	-0.3181	-0.2664	-0.2954	-	-	-	-	-	0.4138
$FLUD_{t1}$	-0.7220	-0.6777	-0.7131	-	-	0.2057	-	-	0.3162
FLU_{t3}	-0.5742	-0.5603	-0.5792	-	-	-	-	-	0.2173
$FLUD_{t3}$	-0.6357	-0.6210	-0.6499	-	-	0.2079	-	-	-
$FLUC_{t3}$	-0.4402	-0.3710	-0.3848	-	0.1996	0.3003	-	0.2161	-0.2804

Table H-3. Brevard County Spearman Rank analyses, Monument to Dune Height (MDH)) and dependent variables at 0.05 significance

	MDH_{t1}	MDH_{t2}	MDH_{t3}	$MDH_{t2\text{-}1}$	$MDH_{t3\text{-}2}$	$MDH_{t3\text{-}1}$	MDH_{tot}	MDH_{f}	POS
UN_{t1}	-	-	-	-	-	-	-	-	-0.2943
UN_{t2}	-	-	-	-	-	-	-	-	-0.2198
UN_{t3}	-	-	-	-	-	-	-	-	-
$UN_{t2\text{-}1}$	-	-	-	-	-	-	-	-	-
$UN_{t3\text{-}2}$	-	0.2365	-	-	-0.2469	-	-0.1885	-	0.3242
$UN_{t3\text{-}1}$	-	0.1481	-	-	-	-	-	-	0.2254
UH_{t1}	-	-	-	-	-	-	-	-	-0.2969
UH_{t2}	-	-	-	-	-	-	-	-	-0.2003
UH_{t3}	-	-	-	-	-	-	-	-	-
$UH_{t2\text{-}1}$	-	-	-	-	-	-	-	-	-
$UH_{t3\text{-}2}$	-	0.2437	-	-	-0.2464	-	-0.1890	-	0.3201
$UH_{t3\text{-}1}$	-	-	-	-	-	-	-	-	0.2240
IMP_{t1}	-0.2990	-0.2748	-	-	-	-	0.2816	-	-0.6686
IMP_{t2}	-0.3363	-0.3075	-0.1722	-	-	-	0.2385	-	-0.6632
IMP_{t3}	-0.3605	-0.3002	-0.1990	-	-	-	0.1764	-	-0.6603
$IMP_{t2\text{-}1}$	-	-	-	0.2187	-	0.1928	-	0.2315	-0.2210
$IMP_{t3\text{-}2}$	-	-	-	0.2129	-	-	-	-	-
$IMP_{t3\text{-}1}$	-	-	-	0.2501	-	0.2142	-	-	-0.2552
PIM_{t1}	-0.2701	-0.2522	-	-	-	-	0.3075	-	-0.6456
PIM_{t2}	-0.2609	-0.2811	-	-	-	-	0.2959	-	-0.6499
PIM_{t3}	-0.2792	-0.2684	-0.1035	-	-	-	0.2494	-	-0.6614
$PIM_{t2\text{-}1}$	-	-	-	0.1691	-	-	-	0.1913	-0.2331
$PIM_{t3\text{-}2}$	-	-	-	0.2067	-	-	-	-	-
$PIM_{t3\text{-}1}$	-	-	-	-	-	-	-	0.2055	0.2753
ACC	0.2420	-	-	-	-	-	-0.3238	-	0.6800
DACC	-0.3157	-0.3022	-0.2412	-	-	-	0.2894	-0.2130	-0.6897
POS	0.5124	0.3509	0.2960	-	-	-	-0.3391	-	1.0000
C_{t1}	-0.3228	-0.2868	-	-	-	-	0.2741	-	-0.6226
C_{t2}	-0.3413	-0.3022	-	-	-	-	0.2355	-	-0.6197
C_{t3}	-0.3534	-0.2978	-0.1875	0.0381	-	-	0.1820	-	-0.6211
$C_{t2\text{-}1}$	-	-	-	0.2239	-	0.1758	-	0.2069	-0.2922
$C_{t3\text{-}2}$	-	-	-	-	-	-	-	-	-
$C_{t3\text{-}1}$	-	-	-	0.2462	-	0.2178	-	0.2385	-0.3481
$FLUD_{t1}$	-0.2869	-0.2363	-	-	-	-	0.2523	-	-0.8103
FLU_{t3}	-0.4047	-0.3649	-0.2408	-	-	-	0.2007	-	-0.6171
$FLUD_{t3}$	-0.3641	-0.3365	-	-	-	-	0.3037	-	-0.6541
$FLUC_{t3}$		-	-	-	-	-	0.2593	-	-

Table H-4. Brevard County Spearman Rank analyses, Maximum Dune Height to NGVD (DHBW)) and dependent variables at 0.05 significance

	$DHBW_{t1}$	$DHBW_{t2}$	$DHBW_{t3}$	$DHBW_{t2-1}$	$DHBW_{t3-2}$	$DHBW_{t3-1}$	$DHBW_{tot}$	$DHBW_{f}$
UN_{t1}	-	0.2506	-	-	-	-	0.2602	-
UN_{t2}	-	0.2599	-	-	-	-	0.2855	-
UN_{t3}	-	0.2392	-	-	-	-	0.1951	-
UN_{t2-1}	-	-	-	-	-	-	-	-
UN_{t3-2}	-	-	-	-	-	-	-	-
UN_{t3-1}	-	-	-	-	-	-	-	-
UH_{t1}	-	0.2680	-	-	-	-	0.2875	-
UH_{t2}	-	0.2562	-	-	-	-	0.3030	-
UH_{t3}	-	0.2358	-	-	-	-	0.2204	-
UH_{t2-1}	-	-	-	-	-	-	-	-
UH_{t3-2}	-	-	-	-	-	-	-	-
UH_{t3-1}	-	-	-	-	-	-	-	-
IMP_{t1}	-	0.2644	-	-	-	-	0.2583	-
IMP_{t2}	-	0.3328	-	-	-	-	0.2874	-
IMP_{t3}	0.1738	0.3632	0.2119	-	-	-	0.2172	-
IMP_{t2-1}	-	0.2560	-	-	-	-	0.1793	-
IMP_{t3-2}	-	-	-	-	-	-	-	-
IMP_{t3-1}	-	0.3205	0.2391	-	-	-	-	-
PIM_{t1}	-	0.3237	-	-	-	-	0.3112	-
PIM_{t2}	-	0.3785	-	-	-	-	0.3633	-
PIM_{t3}	0.1760	0.4146	-	-	-	-	0.3084	-
PIM_{t2-1}	-	0.2333	-	-	-	-	0.1995	-
PIM_{t3-2}	-	-	-	-	-	-	-	-
PIM_{t3-1}	-	0.3050	-	-	-	-	-	-
ACC	-	-0.2798	-	-0.1865	-	-	-0.3219	-
DACC	-	-	-	-	-	-	0.3075	-
POS	-0.1723	-0.4049	-0.3425	-	-	-	-0.3997	-
C_{t1}	-	0.2269	-	-	-	-	0.2446	-
C_{t2}	0.1832	0.2772	-	-	-	-	0.2255	-
C_{t3}	0.1809	0.3012	0.1801	-	-	-	0.1743	-
C_{t2-1}	-	0.2126	-	-	-	-	-	-
C_{t3-2}	-	-	-	-	-	-	-	-
C_{t3-1}	-	0.2493	-	-	-	-	-	-
$FLUD_{t1}$	-	0.4077	-	-	-	-	0.3694	-
FLU_{t3}	-	0.3737	-	-	-0.1885	-	0.2890	-
$FLUD_{t3}$	0.1923	0.3907	-	-	-0.2011	-	0.3732	-
$FLUC_{t3}$	0.1448	0.2774	-	-	-	-	0.2784	-

Table H-5. St Johns County Spearman Rank analyses, Beach Width (BW)) and dependent variables at 0.05 significance

	BW_{t1}	BW_{t2}	BW_{t3}	BW_{t2-1}	BW_{t3-2}	BW_{t3-1}	BW_{tot}	BW_{f}	LT
UN_{t1}	0.2060	0.3999	-	-	-	0.1840	0.2060	0.3999	0.2608
UN_{t2}	0.1838	0.2750	-0.1189	-0.0557	0.0725	0.2529	0.1838	0.2750	0.1900
UN_{t3}	0.2324	0.3092	0.2500	0.2620	-	-	0.2873	0.1892	-
UN_{t2-1}	-	-	-	-	-	-	-	-	-
UN_{t3-2}	-	-	-	-	-	-	-	-	-
UN_{t3-1}	-	-	-	-	-	-	-	-	-
UH_{t1}	-	0.2239	0.2066	0.2029	-	0.2192	-	0.2113	-
UH_{t2}	-	-	-	-	-	-	-	-	-
UH_{t3}	-	-	-	-	-	-	-	-	-
UH_{t2-1}	-	-	-	-	-	-	-	-	-
UH_{t3-2}	-	-	-0.2085	-0.1378	-	-0.1751	-	-	-
UH_{t3-1}	-	-	-0.1994	-	-	-	-	-	-
IMP_{t1}	0.1835	0.3345	0.3985	0.3097	0.2804	0.4247	-	0.4125	0.2528
IMP_{t2}	0.3873	0.4597	0.5115	0.3817	0.1964	0.4111	0.3383	0.3996	0.3249
IMP_{t3}	0.4251	0.4818	0.4761	0.3735	0.1226	0.3972	0.3896	0.3531	0.2786
IMP_{t2-1}	0.4174	0.3883	0.3807	0.3007	-	-	0.3121	0.2463	0.3551
IMP_{t3-2}	0.2022	0.1749	-	-	-	0.1735	-	-	-
IMP_{t3-1}	0.4267	0.3816	0.3538	0.2769	-	0.2851	0.3188	0.2092	0.2536
PIM_{t1}	-	0.2350	0.2323	0.2046	-	0.2345	-	0.2280	-
PIM_{t2}	0.2668	0.3243	0.3291	0.2641	-	0.2388	0.2385	0.2026	0.2631
PIM_{t3}	0.3403	0.3661	0.3162	0.2624	-	0.2217	0.3039	-	0.2291
PIM_{t2-1}	0.3063	0.2812	0.2456	0.2166	-	-	-	-	-
PIM_{t3-2}	-	-	-	-	-	-	-	-	-
PIM_{t3-1}	0.3478	0.2842	0.2203	0.1936	-	-	-	-	-
ACC	-0.4153	-0.4123	-0.4938	-0.2703	-0.3424	-0.4327	-0.2921	-0.4396	-
DACC	0.1909	-	-	-	-0.1781	-0.1829	-	-0.2008	-
POS	0.4149	0.2175	0.2154	-	0.2062	-	-	-	0.2296
C_{t1}		0.1789	-	-	0.1799	0.2101	-	0.1965	-
C_{t2}	0.3524	0.3608	0.3945	0.2593	-	-	0.3044	0.2484	-
C_{t3}	0.3859	0.3753	0.3657	0.2655	-	0.2611	0.2878	0.2167	0.1901
C_{t2-1}	0.3775	0.3816	0.3703	0.2736	-	0.2402	-	0.2274	-
C_{t3-2}	-	-	-	-	-	-	-	-	-
C_{t3-1}	-	-	-	-	-	0.2143	0.2510	0.1842	0.1720
$FLUD_{t1}$	0.4366	0.1713	-	-	-	-0.1719	0.1759	-	0.1966
FLU_{t2}	0.3456	0.5516	0.5311	0.5649	-	0.5641	0.4264	0.5510	0.4314
$FLUD_{t2}$	0.2363	0.3814	0.2995	0.4159	-	0.3304	0.2995	0.2600	0.3748
$FLUC_{t2}$	-	-	-	-	-	-	-	-	-
FLU_{t3}	0.3400	0.3739	0.3166	0.3416	-0.0973	0.2559	0.3505	0.2433	0.2175
$FLUD_{t3}$	0.2737	0.2320	-	0.1778	-0.3726	-	0.2501	-	0.1958
$FLUC_{t3}$		-	-	-	-	-	-	-	-

Table H-6. St Johns County Spearman Rank analyses, Dune Height (DH) and) and dependent variables at 0.05 significance

	DH_{t1}	DH_{t2}	DH_{t3}	DH_{t2-1}	DH_{t3-2}	DH_{t3-1}	DH_{tot}	DH_f	OR
UN_{t1}	-	-	-	0.1840	-	0.2308	0.1894	0.1701	-
UN_{t2}	-	-	-	0.2529	-	0.2493	-	0.1673	-
UN_{t3}	-	-	-	-	-	-	-	0.1737	-
UN_{t2-1}	-	-	-	0.1873	-	0.1799	-	-	-
UN_{t3-2}	-	-	-	-	-	-	-	-	-
UN_{t3-1}	-	-	-	0.2353	0.0742	0.1756	-	-	0.1951
UH_{t1}	-	-	-	-	-	-	-	-	-
UH_{t2}	-	-	-	-	-	-	-	-	-
UH_{t3}	-	-	-	-	-	-	-	-	-
UH_{t2-1}	-	-	-	-	-	-	-	-	-
UH_{t3-2}	-	-	-	-	-	-	-	-	-
UH_{t3-1}	-	-	-	-	-	-	-	-	0.2006
IMP_{t1}	-0.1780	-	-	0.1968	-	-	-	0.1765	-
IMP_{t2}	-0.1792	-	-	0.1902	0.2141	0.3157	0.2651	0.2793	-
IMP_{t3}	-	-	-	-	0.2119	0.2594	0.2341	0.2236	-
IMP_{t2-1}	-	-	-	-	0.2358	0.2493	0.1480	0.2305	-
IMP_{t3-2}	-	-	-	-	-	0.1856	-	-	-
IMP_{t3-1}	-	-	-	-	0.1765	0.1765	-	0.1718	-
PIM_{t1}	-	-	-	-	-	-	-	-	-
PIM_{t2}	-	-	-	-	-	0.1967	-	-	-
PIM_{t3}	-	-	-	-	-	-	-	-	-
PIM_{t2-1}	-	-	-	-	0.1786	0.1699	-	0.1838	-
PIM_{t3-2}	-	-	-	-	-	-	-	-	0.1890
PIM_{t3-1}	-	-	-	-	-	-	-	-	-
ACC	0.1837	-	-	-0.1817	-0.1980	-	-	-	0.2122
DACC	-	-	0.3642	-	-	-	-	-	0.2337
POS	-	0.2374	0.2126	-	-	-	0.2064	-	-0.3997
C_{t1}	-	-	-	-	-	0.1168	0.2247	0.0231	-
C_{t2}	-	-	-	-	-	-	0.2269	-	-
C_{t3}	-	-	-	-	-	0.0989	-	-	-
C_{t2-1}	-	-	-	-	-	-	-	-	-
C_{t3-2}	-	-	-	-	-	-	-	-	-
C_{t3-1}	-	-	-	-	-	-	-	-	-
$FLUD_{t1}$	0.3536	0.4350	0.4533			-0.0416	-0.1914	-0.0488	-
FLU_{t2}	-	-	-	-	0.2272	0.1800	0.2616	-	-
$FLUD_{t2}$	-	-	-	-	-	-	-	-	-
$FLUC_{t2}$	-0.1734	-0.1779	-	-	-	-	-	0.2082	-
FLU_{t3}	-	-	-	-	-	0.1978	0.1487	0.0996	0.1908
$FLUD_{t3}$	-	0.1772	0.2282	-	-	-	-0.1210	-0.0775	-
$FLUC_{t3}$	-0.1861	-0.1748	-0.1933	-	-	-	0.0722	0.1800	-

Table H-7. St Johns County Spearman Rank analyses, Monument to Dune Height (MDH)) and dependent variables at 0.05 significance

	MDH_{t1}	MDH_{t2}	MDH_{t2}	MDH_{t2-1}	MDH_{t3-2}	MDH_{t3-1}	MDH_{tot}	MDH_{f}	POS
UN_{t1}	-	-	-	0.2820	-	0.2216	0.2920	-	-
UN_{t2}	-	-	-	0.2435	-	0.2308	0.2893	-	-
UN_{t3}	-	-	-	0.2320	-	-	0.3093	-	-
UN_{t2-1}	-	-	-	-	-	-	-	-	-
UN_{t3-2}	-	-	-	-	-	-	-	-	-
UN_{t3-1}	-	-	-	-	-	0.2215	0.2367	-	-
UH_{t1}	-	-	-	-	-	-	-	-	-
UH_{t2}	-	-	-	-	-	-	-	-	-
UH_{t3}	-	-	0.2519	-	-	-	-	-	-
UH_{t2-1}	-	-	-	-	-	-	-	-	-
UH_{t3-2}	-	-	-	-	-	-	-	-	-
UH_{t3-1}	-	-	-	-	-	-	-	-	-
IMP_{t1}	-0.1996	-	-	0.2313	-	0.2470	0.3334	-	-
IMP_{t2}	-0.2095	-	-	-	-	-	0.3869	-	-
IMP_{t3}	-	-	-	-	-	-	0.2460	-	-
IMP_{t2-1}	-	-	-	-	-	-	-	-	0.2197
IMP_{t3-2}	-	-	-	-	-	-	-	-	-
IMP_{t3-1}	-	-	-	-	-	-	-	-	0.2112
PIM_{t1}	-	-	-	-	-	-	-	-	-
PIM_{t2}	-	-	-	-	-	-	-	-	-
PIM_{t3}	-	-	-	-	-	-	-	-	0.1792
PIM_{t2-1}	-	-	-	-	-	-	-	-	0.2200
PIM_{t3-2}	-	-	-	-	-	-	-	-	-
PIM_{t3-1}	-	-	-	-	-	-	-	-	0.2628
ACC	-	-	-	-	-	-0.2204	-0.2300	-0.2067	-
DACC	-	-	-	-	-	0.0297	-	-	-
POS	0.4046	-	-	-0.2965	-	-0.2247	-	-0.2727	-
C_{t1}	-	-	-	-	-	-	-	-	-
C_{t2}	-	-	-	-	-	-	-	-	0.1874
C_{t3}	-	-	-	-	-	-	-	-	0.1848
C_{t2-1}	-	-	-	-	-	-	0.2433	-	0.2094
C_{t3-2}	-	-	-	-	-	-	-	-	-
C_{t3-1}	-	-	-	-	-	-	-	-	0.1847
$FLUD_{t1}$	0.1967	-	-	-0.2008	-	-	-	-0.1972	0.3633
FLU_{t2}	0.2261	-	-	0.3356	-	0.2922	-	0.2618	-
$FLUD_{t2}$	-	-	-	-	-	-	-	-	-
$FLUC_{t2}$	-0.2321	-	-	-	-	-	-	-	-
FLU_{t3}	-	-	0.3641	0.3496	-	0.4074	0.2244	0.3390	-
$FLUD_{t3}$	-	-	-	-	-	0.1959	-	-	-0.1932
$FLUC_{t3}$	-	-	-	-	-	-	-	-	-

Table H-8. St Johns County Spearman Rank analyses, Maximum Dune Height to NGVD (DHBW)) and dependent variables at 0.05 significance

	$DHBW_{t1}$	$DHBW_{t2}$	$DHBW_{t3}$	$DHBW_{t2-1}$	$DHBW_{t3-2}$	$DHBW_{t3-1}$	$DHBW_{tot}$	$DHBW_{f}$
UN_{t1}	0.2297	0.3453	0.3619	0.2686	0.2065	0.3653	-	0.3662
UN_{t2}	0.1715	0.2807	0.2709	0.2204	0.1478	0.2964	-	0.2896
UN_{t3}	-	-	-	0.1813	-	-	0.1710	-
UN_{t2-1}	-	-	-	-	-	-	-	-
UN_{t3-2}	-	-	-	-	-	-	-	-
UN_{t3-1}	-	-	-	-	-	-	-	-
UH_{t1}	-	0.2268	0.2101	0.2046	-	0.2400	-	0.2362
UH_{t2}	-	-	-	-	-	-	-	-
UH_{t3}	-	-	-	-	-	-	-	-
UH_{t2-1}	-	-	-	-	-	-	-	-
UH_{t3-2}	-	-	-0.2370	-	-	-0.2028	-	-
UH_{t3-1}	-	-	-	-	-	-0.1885	-	-
IMP_{t1}	0.1890	0.3333	0.3599	0.2918	0.1812	-	0.1783	0.3910
IMP_{t2}	0.3586	0.4472	0.4428	0.2944	0.0908	0.3194	0.2245	0.3549
IMP_{t3}	0.3792	0.4564	0.4304	0.3153	0.0780	0.3503	0.2747	0.3444
IMP_{t2-1}	0.3641	0.3820	0.3378	0.2142	-	0.1678	0.1453	0.1853
IMP_{t3-2}	-	-	-	-	-	-	-	-
IMP_{t3-1}	0.3496	0.3547	0.3118	0.2047	-	0.2338	0.1881	0.2035
PIM_{t1}	-	-	0.2341	0.2251	-	-	-	0.2593
PIM_{t2}	0.2333	0.3441	0.3019	0.2421	-	0.2282	0.1739	0.2414
PIM_{t3}	0.2899	0.3758	0.3110	0.2506	-	0.2428	0.2163	0.2157
PIM_{t2-1}	0.2568	0.2978	0.2266	0.1796	-	-	-	-
PIM_{t3-2}	-	-	-	-	-	-	-	-
PIM_{t3-1}	0.2784	0.2881	0.2172	-	-	-	-	-
ACC	-0.3860	-0.3658	-0.4567	-0.2376	-0.2337	-0.4035	-0.2484	-0.4117
DACC	0.1838	-	-	-	-	-	-	-
POS	0.3237	0.2272	0.2537	-	-	-	-	-
C_{t1}	-	0.2019	0.2001	0.1786	-	0.1890	0.1927	0.1962
C_{t2}	0.3029	0.3629	0.3492	0.2457	-	-	-	0.2179
C_{t3}	0.3405	0.3847	0.3798	0.2490	-	0.2511	0.2411	0.2283
C_{t2-1}	0.3416	0.3909	0.3456	0.2702	-	-	-	-
C_{t3-2}	-	-	-	-	-	-	-	-
C_{t3-1}	0.2954	0.3199	0.3117	0.1930	-	0.1918	0.1928	0.1845
$FLUD_{t1}$	0.3952	0.1799	0.1340	-0.0415	-	-0.1247	0.0561	-0.2102
FLU_{t2}	0.3823	0.4916	0.4854	0.4562	-	0.4453	0.2959	0.4758
$FLUD_{t2}$	0.2700	0.3681	0.3230	0.3692	-	0.2989	0.1959	0.2879
$FLUC_{t2}$	-	-	-	-	-	-	-	-
FLU_{t3}	0.3320	0.2921	0.2359	0.2108	-	-	-	-
$FLUD_{t3}$	0.2560	0.2074	-	-	-0.2643	-	-	-0.1680
$FLUC_{t3}$	-	-	-	-	-	-	-	-

Table H-9. St Johns County Spearman Rank analyses (Ponte Vedra to Vilano Beach, Monument 1 to 120), Beach Width (BW) and) and dependent variables at 0.05 significance

	BW_{t1}	BW_{t2}	BW_{t3}	BW_{t2-1}	BW_{t3-2}	BW_{t3-1}	BW_{tot}	BW_{f}	LT
UN_{t1}	-	-	0.4039	-	0.3170	0.4436	-	0.4017	0.2630
UN_{t2}	-	-	0.3144	-	-	0.3299	-	0.2804	-
UN_{t3}	-	-	-	-	-	-	-	-	-0.3652
UN_{t2-1}	-	-	-	-	-	-	-	-	-
UN_{t3-2}	-	-	-0.3027	-	-	-	-	-	-
UN_{t3-1}	-	-	-0.3247	-	-	-	-	-	-
UH_{t1}	-	-	-	-	-	-	-	-	-
UH_{t2}	-	-	-	-	-	-	-	-	-
UH_{t3}	-	-	-0.2808	-	-	-0.3625	-	-0.3892	-
UH_{t2-1}	-	-	-0.2755	-	-	-0.2755	-	-0.2809	-
UH_{t3-2}	-	-0.2641	-0.5023	-0.2513	-0.2698	-0.4781	-	-0.4755	-
UH_{t3-1}	-	-0.2578	-0.5390	-0.2528	-0.3171	-0.5457	-	-0.5392	-
IMP_{t1}	-	-	0.4075	-	0.3316	0.4508	-	0.4104	-
IMP_{t2}	-	0.2443	0.4424	-	-	0.3611	-	0.3469	-
IMP_{t3}	-	-	0.2205	-	-	0.2456	-	0.2668	-
IMP_{t2-1}	-	-	-	-	-	-	-	-	-0.1206
IMP_{t3-2}	-	-	-	-	-	-	-	-	-
IMP_{t3-1}	-	-	-	-	-	-	-	-	-
PIM_{t1}	-	-	-	-	-	-	-	-	-0.0181
PIM_{t2}	-	-	-	-	-	-	-	-	-
PIM_{t3}	-	-	-	-	-	-	-	-	-
PIM_{t2-1}	-	-	-	-	-	-	-	-	-
PIM_{t3-2}	-	-0.2454	-0.3233	-	-	-0.2989	-	-0.2938	-
T6PIM	-	-	-0.3230	-	-	-0.3239	-	-0.2965	-
ACC	0.3419	-	-0.3229	-	-0.3408	-0.5314	-	-0.5454	0.5277
DACC	0.2437	-	-	-0.2741	-	-0.3572	-	-0.3957	-
POS	-	-0.3023	-0.7204	-0.4659	-0.5108	-0.8604	-	-0.8240	-
C_{t1}	-	-	0.2926	-	-	0.3130	-	0.2877	-
C_{t2}	-	-	-	-	-	-	-	-	-
C_{t3}	-	-	-	-	-	-	-	-	-0.2578
C_{t2-1}	-	-	-	-	-	-	-	-	-
C_{t3-2}	-	-	-	-	-	-	-	-	-0.3905
C_{t3-1}	-	-	-	-	-	-	-	-	-
$FLUD_{t1}$	0.2853	-	-0.5217	-0.3791	-0.4204	-0.7179	-	-0.7008	-
FLU_{t2}	-	-	-	-	-	-	-	-	-
$FLUD_{t2}$	-	-	-	-	-	-	-	-	-
$FLUC_{t2}$	-	-	-	-	-	-	-	-	-
FLU_{t3}	-	-	-	-	-	0.3004	-	0.3544	-
$FLUD_{t3}$	0.2909	-	-0.2992	-	-0.3700	-0.5325	-	-0.5146	-
$FLUC_{t3}$	-	-	-	-	-	-	-	-	-

Table H-10. St Johns County Spearman Rank analyses (Ponte Vedra to Vilano Beach, Monument 1 to 120), Dune Height (DH)) and dependent variables at 0.05 significance

	DH_{t1}	DH_{t2}	DH_{t3}	DH_{t2-1}	DH_{t3-2}	DH_{t3-1}	DH_{tot}	DH_f	OR
UN_{t1}	-0.3624	-0.4425	-0.3680	-	-	-	-	-	-
UN_{t2}	-0.2830	-0.3780	-0.2961	-	-	-	-	-	-
UN_{t3}	-	-0.2556	-	-	-	-	-	-	-
UN_{t2-1}	-	-	-	-	-	-	-	-	-
UN_{t3-2}	-	-	-	-	-	-	-	-	-
UN_{t3-1}	-	-	-	-	-	-	-	-	-
UH_{t1}	-	-	-	-	-	-	-	-	-
UH_{t2}	-	-	-	-	-	-	-	-	-
UH_{t3}	-	-	-	-	-	-	-0.2660	-	-
UH_{t2-1}	-	-	-	-	-	-	-	-	-
UH_{t3-2}	0.2451	0.3268	0.2901	-	-	-	-0.2445	-	-
UH_{t3-1}	0.2835	0.3580	0.2898	-	-	-	-0.3642	-	-
IMP_{t1}	-0.3814	-0.4558	-0.3894	-	-	-	-	-	-
IMP_{t2}	-0.4611	-0.4809	-0.4260	-	-	0.2634	-	-	-
IMP_{t3}	-0.3577	-0.3666	-0.2880	-	0.2851	0.3029	0.2586	0.3022	-
IMP_{t2-1}	-	-	-	-	-	-	-	-	-
IMP_{t3-2}	-	-	-	-	-	-	-	-	-
IMP_{t3-1}	-	-	-	-	-	-	-	-	-
PIM_{t1}	-	-0.2917	-0.2784	-	-	-	-	-	-
PIM_{t2}	-	-	-	-	-	-	-	-	-
PIM_{t3}	-	-	-	-	-	-	-	-	-
PIM_{t2-1}	-	-	-	-	-	-	-	-	-
PIM_{t3-2}	-	-	-	-	-	-	-	-	-
PIM_{t3-1}	-	-	-	-	-	-	-	-	-
ACC	0.5417	0.5648	0.4367	-0.2534	-0.3294	-0.3395	-0.4954	-0.3297	0.3536
DACC	0.3441	0.3352	0.3625	-	-	-	-0.3063	-0.1192	-
POS	0.6289	0.6626	0.5504	-	-0.3712	-0.3954	-0.5528	-0.3218	-
C_{t1}	-0.3334	-0.3578	-0.3855	-	-	-	-	-	-
C_{t2}	-0.3180	-0.2667	-0.2991	-	-	-	-	-	-
C_{t3}	-	-	-	-	-	-	-	-	-
C_{t2-1}	-	-	-	-	-	-	-	-	-
C_{t3-2}	-	-	-	-	-	-	-	-	-
C_{t3-1}	-	-	-	-	-	-	-	-	-
$FLUD_{t1}$	0.5726	0.5799	0.4931	-	-0.3110	-0.4183	-0.4592	-0.3538	0.3339
FLU_{t2}	-	-	-	-	-	-	-		-
$FLUD_{t2}$	-	-	-	-	-	-	-		-
$FLUC_{t2}$	-	-	-	-	-	-	-		-
FLU_{t3}	-0.2788	-	-	-	-	-	-	-	-
$FLUD_{t3}$	0.3183	0.3795	0.3012	-	-	-0.3048	-	-0.3765	0.3876
$FLUC_{t3}$	-0.2802	-0.2787	-0.2823	0.1577	-	-	-	0.3051	-

Table H-11. St Johns County Spearman Rank analyses (Ponte Vedra to Vilano Beach, Monument 1 to 120), Monument to Dune Height (MDH)) and dependent variables at 0.05 significance

	MDH_{t1}	MDH_{t2}	MDH_{t3}	$MDH_{t2\text{-}1}$	$MDH_{t3\text{-}2}$	$MDH_{t3\text{-}1}$	MDH_{tot}	MDH_{f}	POS
UN_{t1}	-0.3598	0.3599	-	0.3991	-	-	-	-	-0.4038
UN_{t2}	-	0.3287	-	-	-	-	-	-	-0.2772
UN_{t3}	-	-	-	-	-	-	-	-	-
$UN_{t2\text{-}1}$	0.4571	-	-0.3996	-0.3430	-	-0.4802	-0.3471	-0.4105	-
$UN_{t3\text{-}2}$	-	-	-	-	-	-	-	-	0.2476
$UN_{t3\text{-}1}$	-	-	-	-	-	-	-	-	0.2665
UH_{t1}	-	-	-	-	-	-	-	-	-
UH_{t2}	-	-	-0.3058	-	-	-	-	-	-
UH_{t3}	-	-	-	-	-	-0.3136	-	-0.3371	0.5074
$UH_{t2\text{-}1}$	0.4944	-	-0.5052	-0.4758	-	-0.5801	-0.4724	-0.4949	0.3673
$UH_{t3\text{-}2}$	0.3138	-		-0.3412	-	-	-	-	0.5676
$UH_{t3\text{-}1}$	0.4484	-0.3270	-	-0.4574	-	-0.4076	-0.3486	-0.3462	0.6572
IMP_{t1}	-0.3831	0.3551	-	0.4036	-	-	-	-	-0.4051
IMP_{t2}	-	0.6199	-	0.4688	-0.2987	-	0.4586	-	-0.3396
IMP_{t3}	-	-	-	0.3444	-0.2592	-	0.4928	-	-0.2481
$IMP_{t2\text{-}1}$	-	0.3814	-	-	-0.4656	-	-	-0.3095	-
$IMP_{t3\text{-}2}$	-	-	-	-	-	-	-	-	-
$IMP_{t3\text{-}1}$	-	-	-	-	-	-	-	-	-
PIM_{t1}	-	-	-	-	-	-	-	-	-
PIM_{t2}	-	0.3620	-	-	-0.3106	-	-	-	-
PIM_{t3}	-	-	-	-	-	-	-	-	0.2671
$PIM_{t2\text{-}1}$	0.3169	-	-0.3239	-	-0.4337	-0.3648	-	-0.3948	0.3868
$PIM_{t3\text{-}2}$	-	-	-	-	-	-	-	-	0.3968
$PIM_{t3\text{-}1}$	-	-	-	-	-	-0.3295	-	-	0.6367
ACC	0.4777	-0.4653	-0.2504	-0.6405	-	-0.4556	-0.5022	-0.4282	0.4872
DACC	0.2810	-0.2888	-0.4682	-0.4145	-	-0.5025	-0.4515	-0.4440	-0.3336
POS	0.5936	-0.5216	-0.2879	-0.6501	-	-0.5125	-0.4701	-0.4270	1.0000
C_{t1}	-	-	-	0.3254	-	-	-	-	-
C_{t2}	-	0.4596	-	0.3907	-	-	-	-	-
C_{t3}	-	-	-	-	-	-	-	-	-
$C_{t2\text{-}1}$	-	0.3881	-	0.3031	-	-	0.4241	-	-
$C_{t3\text{-}2}$	-	-	-	-	-	-	-	-	-
$C_{t3\text{-}1}$	-	-	-	-	-	-	-	-	-
$FLUD_{t1}$	0.4898	-0.5425	-0.3559	-0.6188	-	-0.5086	-0.4194	-0.4453	0.9184
FLU_{t2}	-	-	-	-	-	-	-	-	-
$FLUD_{t2}$	-	-	-	-	-	-	-	-	-
$FLUC_{t2}$	-	-	-	-	-	-	-	-	-
FLU_{t3}	-	0.3878	0.3336	0.4982	-	0.3368	0.4125	-	-0.4860
$FLUD_{t3}$	0.5157	-	-	-0.3453	-	-0.4239	-	-0.4490	0.5705
$FLUC_{t3}$	-	-	-	-	-	-	-	-	-

Table H-12. St Johns County Spearman Rank analyses (Ponte Vedra to Vilano Beach, Monument 1 to 120), Maximum Dune Height to NGVD (DHBW)) at 0.05 significance

	$DHBW_{t1}$	$DHBW_{t2}$	$DHBW_{t3}$	$DHBW_{t2\text{-}1}$	$DHBW_{t3\text{-}2}$	$DHBW_{t3\text{-}1}$	$DHBW_{tot}$	$DHBW_{f}$
UN_{t1}	-	-	0.3591	-	-	0.3510	-	-
UN_{t2}	-	-	0.3191	-	-	0.3507	-	0.0248
UN_{t3}	-	-	-	-	-	-	-	-
$UN_{t2\text{-}1}$	-0.3048	-0.2725		-	-	-	-	-
$UN_{t3\text{-}2}$	-	-	-0.3720	-	-	-	-	-
$UN_{t3\text{-}1}$	-0.3023	-0.3344	-0.3945	-	-	-	-	-
UH_{t1}	-	-	-	-	-	-	-	-
UH_{t2}	-	-	-	-	-	-	-	-
UH_{t3}	-	-	-	-	-	-0.2549	-	-0.2466
$UH_{t2\text{-}1}$	-	-	-	-	-	-	-	-
$UH_{t3\text{-}2}$	-	-	-0.4306	-	-	-0.3922	-	-0.3813
$UH_{t3\text{-}1}$	-	-	-0.4148	-	-	-0.4004	-	-0.3872
IMP_{t1}	-	-	0.3673	-	0.2511	0.3667	-	0.2763
IMP_{t2}	-	-	0.3617	-	-	0.3432	-	0.3958
IMP_{t3}	-	-	-	-	-	-	-	0.2862
$IMP_{t2\text{-}1}$	-	-	-	-	-	-	-	-
$IMP_{t3\text{-}2}$	-	-	-	-	-	-	-	-
$IMP_{t3\text{-}1}$	-0.2455	-	-	-	-	-	-	-
PIM_{t1}	-	-	0.2827	-	-	-	-	-
PIM_{t2}	-	-	-	-	-	-	-	-
PIM_{t3}	-	-	-	-	-	-	-	-
$PIM_{t2\text{-}1}$	-	-	-	-	-	-	-	-
$PIM_{t3\text{-}2}$	-	-	-0.2466	-	-	-	-	-
$PIM_{t3\text{-}1}$	-	-	-	-	-	-	-	-
ACC	-	-	-	-	-	-0.3653	-	-0.4091
DACC	-	-	-	-	-	-	-	-
POS	-	-	-0.5142	-0.2427	-0.3763	-0.6256	-	-0.6202
C_{t1}	-	-	0.2976	-	-	0.3316	-	0.3053
C_{t2}	-	-	-	-	-	-	-	0.2571
C_{t3}	-	-	-	-	-	-	-	0.2604
$C_{t2\text{-}1}$	-	-	-	-	-	-	-	-
$C_{t3\text{-}2}$	-0.2505	-	-	-	-	0.2549	-	0.2781
$C_{t3\text{-}1}$	-	-	-	-	-	-	-	-
$FLUD_{t1}$	-	-	-0.3207	-	-0.2841	-0.4695	-	-0.4652
FLU_{t2}	-	-	-	-	-	-	-	-
$FLUD_{t2}$	-	-	-	-	-	-	-	-
$FLUC_{t2}$	-	-	-	-	-	-	-	-
FLU_{t3}	-	-	-	-	-	-	-	-
$FLUD_{t3}$	-	-	-0.2543	-	-	-0.3764	-	-0.3288
$FLUC_{t3}$	-	-	-	-	-	-	-0.2457	-

Table H-13. St Johns County Spearman Rank analyses (Anastasia Island, Monument 140 to 198), Beach Width (BW)) and dependent variables at 0.05 significance

	BW_{t1}	BW_{t2}	BW_{t3}	BW_{t2-1}	BW_{t3-2}	BW_{t3-1}	BW_{tot}	BW_f	LT
UN_{t1}	-	-	-	-	-	-	-	-	-
UN_{t2}	-	-	-	-	-	-	-	-	0.3799
UN_{t3}	-	0.3680	0.3719	0.3979	-	0.4067	-	-	0.5261
UN_{t2-1}	-	0.3784	-	0.4251	-	-	0.3534	-	0.4072
UN_{t3-2}	-	0.3410	0.4020	-	-	0.3465	-	-	0.4840
UN_{t3-1}	-	0.4829	0.4398	0.4662	-	0.4156	0.3367	-	0.5366
UH_{t1}	-	-	-	-	-	-	-	-	0.3160
UH_{t2}	-	-	-	-	-	-	-	-	0.3933
UH_{t3}	-	0.3703	0.3623	0.4130	-	0.3950	-	-	0.5299
UH_{t2-1}	-	0.3915	-	0.4447	-	-	0.3834	-	0.4432
UH_{t3-2}	-	0.3387	0.4084	-	-	0.3469	-	-	0.4694
UH_{t3-1}	-	0.4827	0.4386	0.4684	-	0.4092	0.3407	-	0.5304
IMP_{t1}	-	-	-	-	-	-	-	-	0.3021
IMP_{t2}	-	-	-	-	-	-	-	-	-
IMP_{t3}	-	-	-	-	-	-	-	-	-
IMP_{t2-1}	-	-	-	0.3096	-	0.3183	0.3505	-	-
IMP_{t3-2}	-	-	0.3198	-	-	-	-	-	0.3054
IMP_{t3-1}	-	-	-	-	-	-	-	-	-
PIM_{t1}	-	-	-	-	-	-	-	-	-
PIM_{t2}	-	-	-	-	-	-	-	-	-
PIM_{t3}	-	-	-	-	-	-	-	-	-
PIM_{t2-1}	-	-	-	-	-	-	0.3505	-	-
PIM_{t3-2}	-	-	0.3262	-	-	-	-	-	-
PIM_{t3-1}	-	-	-	-	-	-	-	-	-
ACC	-	0.3272	-	-	-	-	-	-	-
DACC	-	0.3654	0.4446	-	-	0.3696	-	-	0.5574
POS	-	-0.3221	-	-0.3253	-	-	-	-	-
C_{t1}	-	-	-	-	-	-	-	-	-
C_{t2}	-	-	-	-	-	-	-	-	-
C_{t3}	-	-	-	-	-	-	-	-	-
C_{t2-1}	-	-	-	-	-	-	-	-	-
C_{t3-2}	-	-	-	-	-	-	-	-	-
C_{t3-1}	-	-	-	-	-	-	-	-	-
$FLUD_{t1}$	0.4678	0.5403	0.6907	0.3424	-	0.5847	0.3268	0.3510	-
FLU_{t2}	-	-	-	-	-	-	-	-	-
$FLUD_{t2}$	-	-	-	-	-	-	-	-	-
$FLUC_{t2}$	-	-	-	-	-	-	-	-	-
FLU_{t3}	0.4744	0.6945	0.5828	0.5612	-	0.4639	0.5256	-	0.5660
$FLUD_{t3}$	0.5412	0.7298	0.6365	0.5346	-	0.4598	0.5368	-	0.6317
$FLUC_{t3}$	-0.3816	-0.3014	-0.4142	-	-	-0.3371	-	-0.4822	-0.4414

Table H-14. St Johns County Spearman Rank analyses (Anastasia Island, Monument 140 to 198), Dune Height (DH)) and dependent variables at 0.05 significance

	DH_{t1}	DH_{t2}	DH_{t3}	DH_{t2-1}	DH_{t3-2}	DH_{t3-1}	DH_{tot}	DH_f	OR
UN_{t1}	-	-	-	-	-	-	0.4161	-	-
UN_{t2}	-	-	-	0.4443	-	0.3131	0.4774		-
UN_{t3}	-	-	-	0.5030	-	0.3834	0.4837	0.3377	0.3150
UN_{t2-1}	-	-	-	0.4160	-	0.3581	0.3939	-	-
UN_{t3-2}	-0.3135	-	-	0.3508	-	0.3045	-	-	-
UN_{t3-1}	-0.3527	-	-	0.5145	-	0.3902	0.3817	0.3450	-
UH_{t1}	-	-	-		-	-	0.4450	-	-
UH_{t2}	-	-	-	0.4203	-	-	0.4664	-	-
UH_{t3}	-	-	-	0.4817	-	0.3621	0.4857	0.3009	-
UH_{t2-1}	-	-	-	0.3792	-	0.3317	0.3764	-	-
UH_{t3-2}	-0.3250	-	-	0.3745	-	0.3198	-	-	-
UH_{t3-1}	-0.3625	-	-	0.5122	-	0.3882	0.3805	0.3390	-
IMP_{t1}	-	-	-	-	-	-	0.5003	-	
IMP_{t2}	-	-	-	-	-	-	0.4425	-	-
IMP_{t3}	-	-	-	-	-	-	0.3037	-	-
IMP_{t2-1}	-	-	-	-	-	-	0.3786	-	-
IMP_{t3-2}	-	-	-	-	-	-	-	-	-
IMP_{t3-1}	-	-	-	-	-	-	-	-	-
PIM_{t1}	-	-	-	-	-	-	0.5271	-	-
PIM_{t2}	-	-	-	-	-	-	0.3751	-	-
PIM_{t3}	-	-	-	-	-	-	-	-	-
PIM_{t2-1}	-	-	-	-	-	-	0.3141	-	-
PIM_{t3-2}	-	-	-	-	-	-	-	-	-
PIM_{t3-1}	-	-	-	-	-	-	-	-	-
ACC	-	-0.3097	-	-	-	-	-	-	-
DACC	-	-	-	0.4345	0.3201	0.4943	0.5833	0.3260	-
POS	0.7594	0.7550	0.6435	-0.4356	-0.3938	-0.5083	-0.5046	-0.4638	-0.9479
C_{t1}	-	-	-	-	-	-	-	-	-
C_{t2}	-	-	-	-	-	-	-	-	-
C_{t3}	-	-	-	-	-	-	-	-	-
C_{t2-1}	-	-	-	-	-	-	-	-	-
C_{t3-2}	-	-	-	-	-	-	-	-	-
C_{t3-1}	-	-	-	-	-	-	-	-	-
$FLUD_{t1}$	-	-	-	-	-	-	-	-	-
FLU_{t2}	-	-	-	-	-0.3514	-	-	-	-
$FLUD_{t2}$	-	-	-	-	-0.3651	-	-	-	-
$FLUC_{t2}$	-	-	-	-	-	-	-	-	-
FLU_{t3}	-	-	-	-	-	-	-	-	0.3191
$FLUD_{t3}$	-	-	-	-	0.3018	0.3756	-	0.3259	-
$FLUC_{t3}$	-	-	-0.3013	-	-	-	-	-	0.4454

Table H-15. St Johns County Spearman Rank analyses (Anastasia Island, Monument 140 to 198), Monument to Dune Height (MDH)) and dependent variables at 0.05 significance

	MDH_{t1}	MDH_{t2}	MDH_{t3}	MDH_{t2-1}	MDH_{t3-2}	MDH_{t3-1}	MDH_{tot}	MDH_f	POS
UN_{t1}	-	-	-	-	-	-	-	-	-
UN_{t2}	-	-	-	-	-	-	-	-	-
UN_{t3}	-	0.3556	0.4024	0.4028	-	0.4153	0.4810	-	-0.3816
UN_{t2-1}	-	-	-	-	-	-	-	-	-
UN_{t3-2}	-	0.3557	0.4791	-	-	0.4660	0.4419	-	-
UN_{t3-1}	-	0.3343	0.5554	0.3913	-	0.5556	0.5788	0.3425	-0.3253
UH_{t1}	-	-	-	-	-	-	-	-	-
UH_{t2}	-	-	-	-	-	-	-	-	-
UH_{t3}	-	0.3869	0.4240	0.4335	-	0.4460	0.4519	0.3371	-0.3314
UH_{t2-1}	-	-	-	-	-	-	0.3713	-	-
UH_{t3-2}	-	0.3783	0.5004	0.3328	-	0.4863	0.4180	-	-
UH_{t3-1}	-	0.3479	0.5729	0.3936	-	0.5690	0.5789	0.3480	-0.3198
IMP_{t1}	-	-	-	-	-	-	-	-	-0.3013
IMP_{t2}	-	-	-	-	-	-	-	-	-
IMP_{t3}	-	-	-	-	-	-	-	-	-
IMP_{t2-1}	-	-	-	-	-	-	-	-	-
IMP_{t3-2}	-	-	-	-	-	-	-	-	-
IMP_{t3-1}	-	-	-	-	-	-	-	-	-
PIM_{t1}	-	-	-	-	-	-	-	-	-
PIM_{t2}	-	-	-	-	-	-	-	-	-
PIM_{t3}	-	-	-	-	-0.3306	-	-	-	-
PIM_{t2-1}	-	-	-	-	-	-	-	-	-
PIM_{t3-2}	-	-	-	-	-	-	-	-	-
PIM_{t3-1}	-	-	-	-	-	-	-	-	-
ACC	-	-	-	-	-	-	-	-	-0.3757
DACC	-	0.3681	0.5097	0.3556	-	0.4724	0.4983	0.4558	-
POS	-0.3890	-0.4180	-0.4806	-	-	-0.3403	-0.5932	-0.3351	1.0000
C_{t1}	-	-0.3338	-	-	-	-	-	-	-
C_{t2}	-	-	-	-	-	-	-	-	-
C_{t3}	-	-	-	-	-0.3536	-	-	-	-
C_{t2-1}	-	-	-	-	-	-	-	-	-
C_{t3-2}	-	-	-	-	-	-	-	-	-
C_{t3-1}	-	-	-	-	-0.3575	-	-	-	-
$FLUD_{t1}$	-	-	-	-	-	0.3926	-	-	-
FLU_{t2}	-	-	-	-	0.3610	-	-	-	-
$FLUD_{t2}$	-	-	-	-	0.3911	-	-	-	-
$FLUC_{t2}$	-	-	-	-	-	-	-	-	-
FLU_{t3}	-	0.3970	0.3970	0.4100	-	0.4824	-	0.4343	-
$FLUD_{t3}$	-	0.4820	0.4501	0.4909	-	0.5189	-	0.4523	-
$FLUC_{t3}$	-	-	-	-	-	-	-	-	-0.4429

Table H-16. St Johns County Spearman Rank analyses (Anastasia Island, Monument 140 to 198), Maximum Dune Height to NGVD (DHBW)) and dependent variables at 0.05 significance

	$DHBW_{t1}$	$DHBW_{t2}$	$DHBW_{t3}$	$DHBW_{t2-1}$	$DHBW_{t3-2}$	$DHBW_{t3-1}$	$DHBW_{tot}$	$DHBW_{f}$
UN_{t1}	-	-	-	-	-	-	-	-
UN_{t2}	-	-	-	-	-	-	-	-
UN_{t3}	-	-	-	-	-	-	-	-
UN_{t2-1}	-	-	-	-	-	-	-	-
UN_{t3-2}	-	-	-	-	-	-	-	-
UN_{t3-1}	-	-	-	-	-	-	-	-0.2979
UH_{t1}	-	-	0.3208	-	-	-	-	-
UH_{t2}	-	-	-	-	-	-	-	-
UH_{t3}	-	-	-	-	-	-	-	-
UH_{t2-1}	-	-	-	-	-	-	-	-
UH_{t3-2}	-	-	-	-	-	-	-	-0.2954
UH_{t3-1}	-	-	-	-	-	0.3100	-	-0.3154
IMP_{t1}	-	-	0.3128	-	-	-	-	-
IMP_{t2}	-	-	-	-	-	-	-	-
IMP_{t3}	-	-	-	-	-	-	-	-
IMP_{t2-1}	-	-	-	-	-	-	-	-
IMP_{t3-2}	-	-	0.3047	-	-	-	-	-
IMP_{t3-1}	-	-	-	-	-	-	-	-
PIM_{t1}	-	-	-	-	-	-	-	-
PIM_{t2}	-	-	-	-	-	-	-	-
PIM_{t3}	-	-	-	-	-	-	-	-
PIM_{t2-1}	-	-	-	-	-	-	-	-
PIM_{t3-2}	-	-	-	-	-	-	-	-
PIM_{t3-1}	-	-	-	-	-	-	-	-
ACC	-	-	-	-	-	-	-	-
DACC	-	-	-	-	-	-	-	-
POS	-	-	-	-	0.3471	-	-	0.4096
C_{t1}	-	-	-	-	-	-	-	-
C_{t2}	-	-	-	-	-	-	-	-
C_{t3}	-	-	-	-	-	-	-	-
C_{t2-1}	-	-	-	-	-	-	-	-
C_{t3-2}	-	-	-	-	-	-	-	-
C_{t3-1}	-	-	-	-	-	-	-	-
$FLUD_{t1}$	0.5151	-	0.4742	-	-	-	-	-
FLU_{t2}	-	-	-	-	-	-	-	-
$FLUD_{t2}$	-	-	-	-	-	-	-	-
$FLUC_{t2}$	-	-	-	-	-	-	-	-
FLU_{t3}	0.3578	0.4196	-	-	-	-	-	-
$FLUD_{t3}$	0.4477	0.4337	-	-	-	-	-	-
$FLUC_{t3}$	-0.4607	-	-	-	-	-	-	-

APPENDIX I

TIME SERIES GEOMORPHIC VARIABLES

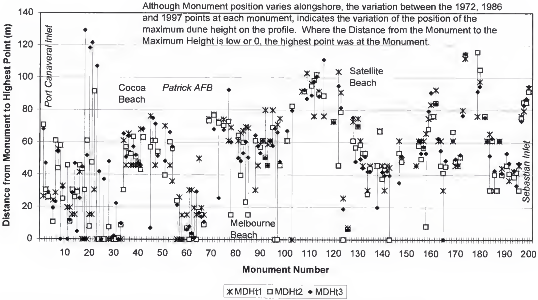

Figure I-1. Brevard County Monument to highest point variations with trend, 1972-1997 (MDH_{t1}, MDH_{t2}, MDH_{t1})

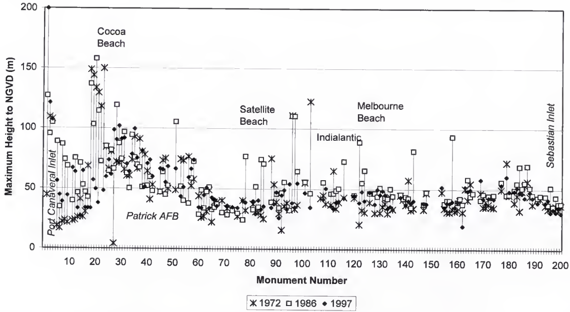

Figure I-2. Brevard County maximum height to NGVD with trend, 1972-1997 ($DHBW_{tl}$, $DHBW_{tl}$, $DHBW_{tl}$)

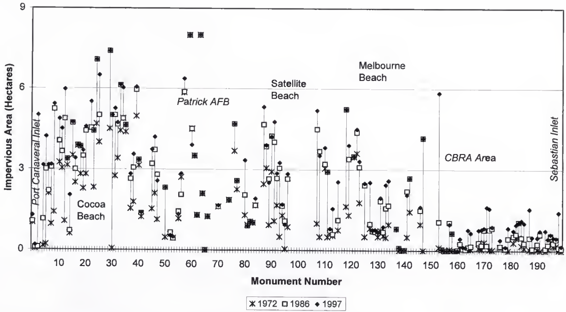

Figure I-3. Brevard County hectares of impervious area with trend, 1972-1997 (IMP_{t1}, IMP_{t1}, IMP_{t1})

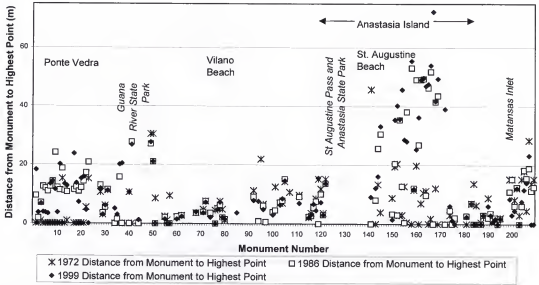

Figure I-4. St. Johns County Monument to highest point variations, 1972-1999 (MDH_{t1}, MDH_{t2}, MDH_{t3})

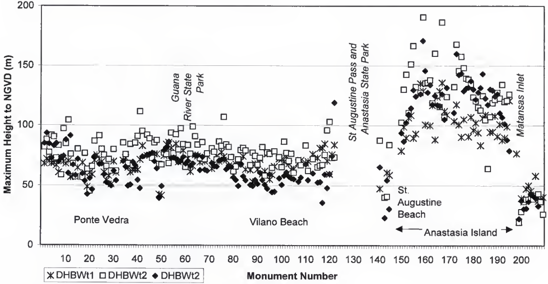

Figure I-5. St. Johns County maximum height to NGVD variations, 1972-1999 ($DHBW_{t1}$, $DHBW_{t2}$, $DHBW_{t3}$)

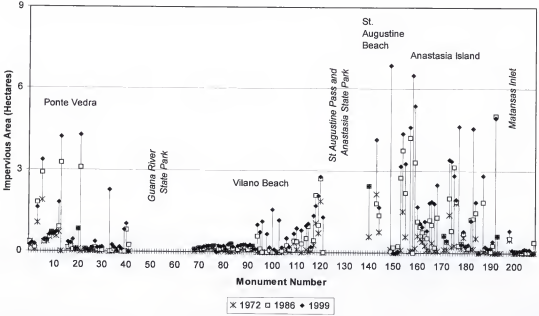

Figure I-6. St. Johns County impervious area variations, 1972-1999 (IMP_{t1}, IMP_{t2}, IMP_{t3})

APPENDIX J: REGRESSION RESULTS, BREVARD AND ST. JOHNS COUNTY

- **Hypothesis 1**: Local geomorphology at each time interval impacts human variables at the same interval

- **Hypothesis 1a:** The local geomorphology influences the actual development. (Conway and Nordstrom, 2003; McMichael, 1977; Miller, 1980).

Table J-1. Hectares of commercial development (C_{t3}), St. Johns County, 1997

Dep. Variable	R^2	Intercept	β_1	Variable	β_2	Variable	β_3	Variable
C_{t3} N=121	0.400	-7.674	-0.022	BW_{t3-1}	-0.347	DH_{t3}	0.056	OR
							β_4	Variable
							0.001	$(DHBW_{t3})^3$

Dependent Variable C_{t3}
Adjusted R-Squared 0.4001

Independent Variable	Regression Coefficient	Standard Error	T-Value (Ho: B=0)	Prob Level	Decision (5%)	Power (5%)
Intercept	-7.673884	3.727084	-2.0590	0.041719	Reject Ho	0.532736
BW_{t3-1}	-2.170779E-02	7.487879E-03	-2.8991	0.004471	Reject Ho	0.819962
DH_{t3}	-0.346913	9.058836E-02	-3.8296	0.000208	Reject Ho	0.966967
OR	5.626662E-02	2.147139E-02	2.6205	0.009944	Reject Ho	0.738595
$(DHBW_{t3})^3$	1.493633E-06	2.071765E-07	7.2095	0.000000	Reject Ho	1.000000
T-Critical	1.980448					
F-Ratio	21.1738			0.000000		1.000000
N=121						

C_{t3} = 1999 Commercial Area (hectares)
BW_{t3-1} = Change in Distance from NGVD to Maximum Dune Height 1972 to 1999 (m)
DH_{t3} = 1999 Maximum Dune Height (m)
OR = Shoreline Orientation (degrees from north)
$(DHBW_{t3})^3$= Cubed Value of 1999 Distance from NGVD to Maximum Dune Height (m)

- **Hypothesis 1b:** The local geomorphology influences the land use control decision-making. (Hails, 1977).

APPENDIX J. Continued

Table J-2. Future land use density ($FLUD_{t1}$), Brevard County, 1972

Dep. Variable	R^2	Intercept	β_1	Variable	β_2	Variable	β_3	Variable
$FLUD_{t1}$ (n=109)	0.649	-89.915	-4.066	DH_{t1}	-21.147	LT	0.821	OR

Dependent Variable	$FLUD_{t1}$
Adjusted R-Squared	0.6488

Independent Variable	Regression Coefficient	Standard Error	T-Value (Ho: B=0)	Prob Level	Decision (5%)	Power (5%)
Intercept	-89.91521	24.67579	-3.6439	0.000418	Reject Ho	0.950599
DH_{t1}	-4.065736	1.308955	-3.1061	0.002433	Reject Ho	0.868188
LT	-21.14734	3.318424	-6.3727	0.000000	Reject Ho	0.999993
OR	0.821133	0.1204817	6.8154	0.000000	Reject Ho	0.999999
T-Critical	1.982597					
F-Ratio	68.1320			0.000000		1.000000
N=109						

$FLUD_{t1}$ = Potential Residential Density, 1974 Comprehensive Plan (units per hectare)
DH_{t1} = 1972 Dune Height (m)
OR = Shoreline Orientation (degrees from north)

Table J-3. Future land use units (FLU_{t3}), Brevard County, 1997

Dep. Variable	R^2	Intercept	β_1	Variable	β_2	Variable
FLU_{t3} (n=106)	0.479	547.346	-71.231	DH_{t3}	-1.337	MDH_{t1}

Dependent Variable	FLU_{t3}
Adjusted R-Squared	0.4789

Independent Variable	Regression Coefficient	Standard Error	T-Value (Ho: B=0)	Prob Level	Decision (5%)	Power (5%)
Intercept	547.3455	51.36757	10.6555	0.000000	Reject Ho	1.000000
DH_{t3}	-71.23122	11.37088	-6.2644	0.000000	Reject Ho	0.999989
MDH_{t1}	-1.337258	0.391753	-3.4135	0.000907	Reject Ho	0.922598
T-Critical	1.982383					
F-Ratio	51.0849		0.000000	1.000000		
N=109						

FLU_{t3} = Potential Units, 1999 Comprehensive Plan
DH_{t3}= 1997 Dune Height (m)
MDH_{t1} = 1972 Distance from Monument to Maximum Height (m)
$(DHBW_{t3-1})^2$ = Squared value of 1972 to 1997 Change is Distance from NGVD to Maximum Dune Height (m)

APPENDIX J. Continued

Table J-4. Future land use units (FLU_{t3}) Brevard County, 1997

Dep. Variable	R^2	Intercept	β_1	Variable	β_2	Variable
FLU_{t3} (n=105)	0.517	608.833	-76.111	DH_{t3}	-0.388	$BW_{t2}ROAD$

Dependent Variable FLU_{t3}
Adjusted R-Squared 0.5173

Independent Variable	Regression Coefficient	Standard Error	T-Value (Ho: B=0)	Prob Level	Decision (5%)	Power (5%)
Intercept	608.8331	49.37215	12.3315	0.000000	Reject Ho	1.000000
DH_{t3}	-76.11123	9.874031	-7.7082	0.000000	Reject Ho	1.000000
$BW_{t2}ROAD$	-0.3883898	8.282633E-02	-4.6892	0.000008	Reject Ho	0.996375
T-Critical	1.983264					
F-Ratio	57.2567			0.000000		1.000000
N= 105						

FLU_{t3} = Potential Units, 1999 Comprehensive Plan
DH_{t3} = 1997 Dune Height (m)
$BW_{t2}ROAD$ = 1986 Beach Width (m) weighted by the position of the parallel access (3-<100m inland, 2-100m to 200m inland, 1->200m inland, 4 more than 1 parallel access road)

Table J-5. Potential residential density, 1979 Comprehensive plan ($FLUD_{t1}$) St. Johns County

Dep. Variable	R^2	Intercept	β_1	Variable	β_2	Variable	β_3	Variable
$FLUD_{t1}$ (n=124)	0.498	9.211	0.022	BW_{t1}	-0.058	OR	0.085	DACC

Dependent Variable $FLUD_{t1}$
Adjusted R-Squared 0.4980

Independent Variable	Regression Coefficient	Standard Error	T-Value (Ho: B=0)	Prob Level	Decision (5%)	Power (5%)
Intercept	9.21105	2.556698	3.6027	0.000458	Reject Ho	0.946737
BW_{t1}	2.233969E-02	3.589396E-03	6.2238	0.000000	Reject Ho	0.999987
OR	-5.830832E-02	1.532162E-02	-3.8056	0.000223	Reject Ho	0.965260
DACC	8.473538E-02	9.816629E-03	8.6318	0.000000	Reject Ho	1.000000
T-Critical	1.979764					
F-Ratio	42.0016		0.000000		1.000000	
N=124						

$FLUD_{t1}$ = Potential Residential Density, 1979 Comprehensive Plan (units per hectare)
BW_{t1} = 1972 Distance from NGVD to Maximum Dune Height (m)
OR = Shoreline Orientation (degrees from north)
DACC = Distance and Direction from Access Point

APPENDIX J. Continued

- **Hypothesis 2**: The dynamic geomorphology impacts human variables

- **Hypotheses 2a**: The dynamic geomorphology indicators influence the actual human variables. (Lundberg and Handegard, 1996; McMichael, 1977; Miller, 1980).

Table J-6. Percent impervious area (PIM_{t3}) Brevard County, 1997

Dep. Variable	R^2	Intercept	β_1	Variable	β_2	Variable	β_3	Variable
PIM_{t3} (n=110)	0.552	-379.003	-0.124	BW_{tot}	-39.611	LT	2.584	OR

Dependent Variable PIM_{t3}
Adjusted R-Squared 0.5515

Independent Variable	Regression Coefficient	Standard Error	T-Value (Ho: B=0)	Prob Level	Decision (5%)	Power (5%)
Intercept	-379.0029	41.24565	-9.1889	0.000000	Reject Ho	1.000000
BW_{tot}	-0.1237122	6.021266E-02	-2.0546	0.042355	Reject Ho	0.530388
LT	-39.61076	9.626182	-4.1149	0.000076	Reject Ho	0.982901
OR	2.583614	0.2599153	9.9402	0.000000	Reject Ho	1.000000
T-Critical	1.982383					
F-Ratio	46.0940			0.000000		1.000000
N=110						

PIM_{t3} = 1997 Percent Impervious Area (%)
BW_{tot} = Total Beach Width Change, absolute value (m)
LT = Long term Change, 1870-1999, (m)
OR = Shoreline Orientation (degrees from north)

- **Hypothesis 2b**: The dynamic geomorphology indicators influence the land use control decision-making. (adaptation of Bush et al., 1999)

Table J-7. Future land use units (FLU_{t3}) Brevard County, 1997

Dep. Variable	R^2	Intercept	β_1	Variable	β_2	Variable
FLU_{t3} (n=113)	0.351	267.215	287.849	LTSW	-0.614	BW_{t2} ROAD

Dependent Variable FLU_{t3}
Adjusted R-Squared 0.3509

Independent Variable	Regression Coefficient	Standard Error	T-Value (Ho: B=0)	Prob Level	Decision (5%)	Power (5%)
Intercept	267.2149	26.93647	9.9202	0.000000	Reject Ho	1.000000
LTSW	287.8491	65.976	4.3629	0.000029	Reject Ho	0.990983
BW_{t2} ROAD	-0.6139084	8.893248E-02	-6.9031	0.000000	Reject Ho	0.999999
T-Critical	1.981567					

APPENDIX J. Continued

F-Ratio	31.5452	0.000000	1.000000
N=113			

FLU_{t3} = Potential Units, 1999 Comprehensive Plan
LTSW = Long term Change, 1870-1999, (m) * Structures Dummy (1-structures present, 0-no structures)
BW_{t2} ROAD-1986 Distance from Monument to NGVD (m) weighted by the position of the parallel access (3-<100m inland, 2-100m to 200m inland, 1->200m inland, 4 more than 1 parallel access road)

Table J-8. Future land use units (FLU_{t3}) St. Johns County south, Monument 141 to Monument 198, 1999

Dep. Variable	R^2	Intercept	β_1	Variable	β_2	Variable	β_3	Variable
FLU_{t3} N=50	0.611	-195.593	0.478	BW_{t2}	-5.080	DH_{t3-1}	1.041	OR

Dependent Variable FLU_{t3}
Adjusted R-Squared 0.6114

Independent Variable	Regression Coefficient	Standard Error	T-Value (Ho: B=0)	Prob Level	Decision (5%)	Power (5%)
Intercept	-195.5933	62.59332	-3.1248	0.003046	Reject Ho	0.864424
BW_{t2}	0.4781096	5.995853E-02	7.9740	0.000000	Reject Ho	1.000000
DH_{t3-1}	-5.080557	2.069582	-2.4549	0.017850	Reject Ho	0.671667
OR	1.04148	0.3812434	2.7318	0.008845	Reject Ho	0.762895
T-Critical	2.011741					
F-Ratio	27.2269			0.000000		1.000000
N=50						

FLU_{t3} = 1999 Potential Future Land Use, Comprehensive Plan (units)
BW_{t2} = 1986 Beach Width (m)
DH_{t3-1} = Change in Maximum Dune Height 1972 to 1999 (m)
OR = Shoreline Orientation (degrees from north)

- **Hypothesis 3:** There are temporally lagged relationships between the actual and dynamic geomorphology variables and the human variables. (Nordstrom, 1987; Van Der Wal, 2004).

Table J-9. Future land use density ($FLUD_{t3}$) St. Johns County south, Monument 141 to Monument 198, 1999

Dep. Variable	R^2	Intercept	β_1	Variable
$FLUD_{t3}$ (n=53)	0.659	1.953	0.000001	$(BW_{t2})^3$

APPENDIX J. Continued

Dependent	$FLUD_{t3}$
Adjusted R-Squared	0.658865

Independent Variable	Regression Coefficient	Standard Error	T-Value (Ho: B=0)	Prob Level	Decision (5%)	Power (5%)
Intercept	1.95296	0.4338925	4.5010	0.000038	Reject Ho	0.992985
$(BW_{t2})^3$	1.296842E-06	1.294047E-07	10.0216	0.000000	Reject Ho	1.000000
F-Ratio	100.4325			0.000000		1.000000
T-Critical	2.006647					
N=53						

$FLUD_{t3}$ = 1999 Future Land Use Density, Comprehensive Plan (units/hectare)
$(BW_{t2})^3$ = Cubed Value of 1986 Distance from NGVD to Maximum Dune Height (m)

- **Hypothesis** 4: The dependent variables will have different relationships with the independent variables in the two separate study areas. (Byrnes et al., 1995).

Table J-10. Future land use density ($FLUD_{t1}$) (also hypothesis 1b) Brevard County, 1972

Dep. Variable	R^2	Intercept	β_1	Variable	β_2	Variable	β_3	Variable
$FLUD_{t1}$ (n=109)	0.649	-89.915	-4.066	DH_{t1}	-21.147	LT	0.821	OR

Dependent Variable	$FLUD_{t1}$
Adjusted R-Squared	0.6488

Independent Variable	Regression Coefficient	Standard Error	T-Value (Ho: B=0)	Prob Level	Decision (5%)	Power (5%)
Intercept	-89.91521	24.67579	-3.6439	0.000418	Reject Ho	0.950599
DH_{t1}	-4.065736	1.308955	-3.1061	0.002433	Reject Ho	0.868188
LT	-21.14734	3.318424	-6.3727	0.000000	Reject Ho	0.999993
OR	0.821133	0.1204817	6.8154	0.000000	Reject Ho	0.999999
T-Critical	1.982597					
F-Ratio	68.1320			0.000000		1.000000
N=109						

$FLUD_{t1}$ = Potential Residential Density, 1974 Comprehensive Plan (units per hectare)
DH_{t1} = 1972 Dune Height (m)
OR = Shoreline Orientation (degrees from north)

Table J-11. Potential residential density, 1979 Comprehensive plan ($FLUD_{t1}$) (also hypothesis 1b) St. Johns County

Dep. Variable	R^2	Intercept	β_1	Variable	β_2	Variable	β_3	Variable
$FLUD_{t1}$ (n=124)	0.498	9.211	0.022	BW_{t1}	-0.058	OR	0.085	DACC

APPENDIX J. Continued

Dependent Variable	$FLUD_{t1}$
Adjusted R-Squared	0.4980

Independent Variable	Regression Coefficient	Standard Error	T-Value (Ho: B=0)	Prob Level	Decision (5%)	Power (5%)
Intercept	9.21105	2.556698	3.6027	0.000458	Reject Ho	0.946737
BW_{t1}	2.233969E-02	3.589396E-03	6.2238	0.000000	Reject Ho	0.999987
OR	-5.830832E-02	1.532162E-02	-3.8056	0.000223	Reject Ho	0.965260
DACC	8.473538E-02	9.816629E-03	8.6318	0.000000	Reject Ho	1.000000
T-Critical	1.979764					
F-Ratio	42.0016			0.000000		1.000000
N=124						

$FLUD_{t1}$ = Potential Residential Density, 1979 Comprehensive Plan (units per hectare)
BW_{t1} = 1972 Distance from NGVD to Maximum Dune Height (m)
OR = Shoreline Orientation (degrees from north),
DACC = Distance and Direction from Access Point

Table J-12. St. Future land use density ($FLUD_{t1}$) Johns County north, Monument 1 to Monument 120, 1972

Dep. Variable	R^2	Intercept	β_1	Variable	β_2	Variable
$FLUD_{t1}$ (n=82)	0.545	-2.272	0.049	BW_{t1}	-1.038	BW_f

Dependent Variable	$FLUD_{t1}$
Adjusted R-Squared	0.5451

Independent Variable	Regression Coefficient	Standard Error	T-Value (Ho: B=0)	Prob Level	Decision (5%)	Power (5%)
Intercept	-2.272346	0.7942346	-2.8611	0.005385	Reject Ho	0.806916
BW_{t1}	4.940527E-02	1.129674E-02	4.3734	0.000037	Reject Ho	0.990872
BW_f	-1.038004	0.1526959	-6.7979	0.000000	Reject Ho	0.999999
T-Critical	1.990063					
F-Ratio	50.1306			0.000000		1.000000
N=82						

$FLUD_{t1}$ = Potential Residential Density, 1979 Comprehensive Plan (units per hectare)
BW_{t1} = 1972 Distance from NGVD to Maximum Dune Height (m)
BW_f = Total Beach Width divided by Net Beach Width

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BIOGRAPHICAL SKETCH

Heidi Jane Lovelace Carter Lannon was born in Sedgefield, England. She is the oldest of four children, all of whom live on different continents. She lived in Wales, Lincolnshire, and Gloucestershire before moving to Malta, where she received early schooling at Sacred Heart and Stella Maris convents. Upon her return to England she attended Easton Royal Primary School. She was sent to Clifton School for Girls in Bristol, where she was the swimming captain and Deputy Head Girl. She attended the University of Ulster in Northern Ireland and received a BSc. with Honours in Environmental Science, under Dr. Bill Carter.

Upon graduation Heidi received funding to attend the University of West Florida. She worked with Dr. James P. Morgan and received a Master of Public Administration with an emphasis in coastal zone management. Heidi worked as a civil servant in land use planning until her decision to return to research under Dr. Joann Mossa at the University of Florida.

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

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This dissertation was submitted to the Graduate Faculty of the Department of Geography in the College of Liberal Arts and Sciences and to the Graduate School and was accepted as partial fulfillment of the requirements for the degree of Doctor of Philosophy.

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